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REVIEW ARTICLE

A REVIEW PAPER ON POST-HARVEST LOSS ON FRUITS AND VEGETABLES

Rachana Tandan Chhetri*, Prajwal Magar, Subarna Kandel, Pariwesh Gnyawali

Department of Horticulture, Mahendra Ratna Multiple Campus, Ilam, Nepal.
****Corresponding author Email: rachana.tandan2022@gmail.com***

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ABSTRACT

Horticultural commodities like fruits and vegetables are highly perishable in nature having a short shelf life. Post-harvest losses on horticulture commodities can be qualitative or quantitative and the quality deterioration can be either physical or physiological. After harvesting, the steps like handling-cooling, cleaning, sorting, grading, packaging, storing, transporting, and marketing must go through high post-harvest losses. Consequently, there will be huge losses that affect the farmer's economic conditions. Considering the fact there are many methods to control the l post-harvest loss of fruits and vegetables, this review paper discusses the causes, effects, and procedures involved in handling fruits and vegetable commodities and explores ways to minimize post-harvest loss and optimize the returns.

KEYWORDS

Handling, Shelf Life, Deteriorate, Horticulture Commodities, Storage, Technology

1. INTRODUCTION

The degradation of food production from harvest to consumption in terms of both quantity and quality is known as post-harvest loss. Quality losses are often seen in developed countries whereas quantity losses are seen more in developing countries (Victor, 2014). Horticulture commodities harvested prematurely and hard harvested on peak maturity results in poor quality and shorter storage life. Such commodities deteriorate much faster than those harvested at the proper stage of maturity (Pokhrel, 2021). Despite the fact that Nepal produces a large number of vegetables and fruits, post-harvest loss in the country ranges from 20% to 50% (Bhattarai, 2018). The principal causes of post-harvest loss can be poverty, inadequate post-harvest handling, lack of appropriate processing technology, poor storage, and poor infrastructure as well as a poor marketing system. The problem of post-harvest loss is dreadful for fruits and vegetables. Around one-third (1.3 billion tonnes) of food produced for human consumption is wasted/lost globally each year (Ridolfi et al., 2018). Fruits and vegetables continue to respire even after harvesting being living organisms, which can remain fresh only till metabolites are continuous. This can make them more prone to spoilage caused by yeast, bacteria, and mold (Adhikari and G.C., 2021). To increase production and to uplift the farmer's economic condition it is necessary to reduce the post-harvest losses. There are various viable technologies that have been used to increase the shelf life of harvested fruits and vegetables in past decades like the use of fungicides, controlled atmospheric storage, cold storage, anti-Tran spirant, growth retardants, wax coating, irradiation, and different types of packaging materials (Rokaya et al., 2016). There are many challenges involved by post-harvest loss of fruits and vegetables so all the growers should focus on the appropriate handling of post-harvest loss.

2. DISCUSSION

The harvesting time of fruits should be at physiological maturity when they attain maximum dry weight and that of vegetable should be harvested at horticultural maturity or field maturity (Pokhrel, 2021). There are many diminution strategies like use of resistant cultivars against post-harvest disease, maximizing yield by keeping care of quality, excellent handling of all the produce at different post-harvest stages. There are various methods that growers apply to fruits and vegetables after harvest. As compared to modern methods there were maximum losses on traditional method. Somehow these days modern methods are playing crucial role in reducing post-harvest loss.

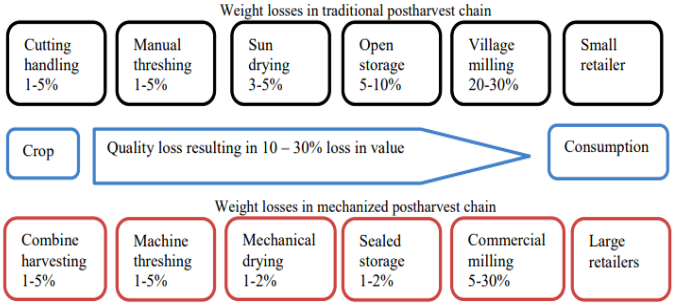

Figure 1: Estimated losses on weight and quality from the post-harvest chain (Source: Victor, 2014)

2.1 Harvesting at Appropriate Stage

Harvesting is the process of gathering ripe crops from the field after having crop's full maturity and for fruits and vegetables it is harvested when the grower's finds appropriate time to consume. Fruits and vegetables are harvested according to their purposes. The harvesting time of fruits should be at physiological maturity when they attain maximum dry weight and that of vegetable should be harvested at horticultural maturity or field maturity (Pokhrel, 2021). During harvesting process, there should be careful handling of the crops to reduce bruising, scratching, and punctures, so it is preferred to harvest during cooler hours of the day, and shading should be provided once the crops are harvested (Ridolfi et al., 2018). After harvest, the product should be shifted to packing shade because the raised field heat during hot seasons can cause wilting and shrivelling

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whereas, during rain, fruits and vegetables should not be harvested as it creates the favourable condition for multiplication of microorganisms (Yahaya, and Mardiyya, 2019). Careful handling and harvesting play an important role in reducing post-harvest loss. Great care and appropriate time should be maintained during harvesting which helps to reduce deterioration and in minimizing post-harvest losses.

Table 1: Maturity Days of Common Vegetables (El-Ramady et al., 2015)

Crops	Early Variety	Late Variety
Tomatoes	65	100
Beets	50	80
Cabbage	62	110
Cauliflower	55	65
Okra	50	60
Mustard	40	60
Onions	85	120
Peas	58	77
Potatoes	90	120
Squash, winter	50	68
Squash, summer	80	120
Okra	50	60
Beans, bush	46	65
Eggplant	70	85
Pumpkin	110	120

Table 2: Maturity Indices of Common Fruits (El-Ramady et al., 2015)

Fruits	Maturity indices
Almonds	Splitting of hull, separation of hull from shell, development of abscission
Banana	No angularity in a cross section of the finger
Cherry	TSS=14%-15%, light red colour
Guava	Colour break stage
Papaya	Skin shows yellowing
Mango	Change in shape, flesh colour yellow to yellowish orange
Kiwi fruit	TSS=6.5%, firmness- 14lbs

2.2 Precooling; Simple Yet Advanced Option

Precooling is suitable for the rapid removal of field heat of the commodity, and it is the first step to managing the temperature which ultimately slows down the physiological process. Immediate cooling after harvest is the most important operation because the increase in field heat activates quality deterioration and gives rise to undesirable changes in metabolism (Pokhrel, 2021). Factors like high microbial activities, high metabolic activity, increased respiration rate, and enhanced ethylene production are monitored/minimized by precooling mechanism and reduce the ripening rate, water loss, and decay thereby preserving quality and extending the shelf life of fruits and vegetables (Ganai et al., 2018). A basic investment to decrease the heat of produce after harvesting can be effective because refrigerated trucks are not designed to cool the fresh commodities (Faqeerzada et al., 2018). Leaves will exhibit wilting in the market or even before reaching the market, reducing the price and appeal of the product to consumers without pre-cooling. There are many methods of cooling like room cooling, forced air cooling, hydro cooling, vacuum cooling, and packaging. Hydro cooling can be considered as a cheap but effective method of precooling, harvested produce is done by dipping them in cold water mixed with a disinfectant such as sodium hypochlorite (Adhikari and G.C., 2021).

2.3 Cleaning

Cleaning is done to remove anything which can damage fruits and vegetables in the coming days. It is the special post-harvest handling operation that is necessary to remove adherences, dirt, latex, and external pathogens structures (Faqeerzada et al., 2018). Appropriate cleaning is one of the important factors to reduce post-harvest loss and also prevents post-harvest diseases and foodborne illness to the consumers (Arah et al., 2016). It is done by using sodium hypochlorite solution, thiabendazole, and chlorinated water having higher PH levels which are very effective.

2.3 Sorting and Grading

Sorting and grading are important criteria to be known when we talk about reducing post-harvest loss. The removal of rotten, damaged, or diseased fruits and vegetables from healthy ones is sorting which reduces the production of ethylene in enormous amounts and can preserve the shelf life of the commodities. Grading is done on the basis of color, size, stage of maturity, or degree of ripening of fruits and vegetables (Arah et al., 2016). Grading helps to remove overripe commodities which automatically increases the shelf life of commodities. Grading can be A, B, C, or 1,2,3, or small, medium, or big, etc. Sizing produce of fruits is optional but may be worthwhile if certain sizes grades receive a higher price as compared to other sizes ("Post-Harvest Loss Management and Quality Control of Fruits and Vegetables in Ethiopia for Securing Food and Nutrition – A Review," 2020). Sorting restrains the spread of various infectious diseases which are harmful to the fruits and vegetables and helps to reduce post-harvest loss. Technically, sorting, and grading help to fetch a higher price in the market by minimizing post-harvest losses, but they are not done effectively due to a lack of suitable storage facilities, lack of knowledge on temperature requirements, the effect of cold chain practices on reducing losses, ethylene sensitive of different commodities, lack of national standards, poor enforcement of skills and standards. Financial resources for grading products play a detrimental role to present a higher degree of post-harvest losses (Rajapaksha et al., 2021).

2.4 Packaging

Packaging is considered one of the important aspects considering post-harvest loss reduction in fruits and vegetables. It protects commodities from mechanical injuries, tampering, and contamination from physical, chemical, and biological sources which also enables food products to be safe from these injuries (Arah et al., 2016). Proper packaging prevents quality deterioration maintains freshness as well as protects against physical damage during transportation (Ridolfi et al., 2018). During transportation, containers should be clean, smooth, and well-ventilated but the specific type depends on the specific crops. Packaging can be of different types i.e., active packaging and intelligent packaging. Active packaging prolongs the shelf life maintaining the quality of the product whereas intelligent packaging helps to monitor the condition of packaged food during transport and storage (Prasad and Kochhar, 2014). For different fruits and vegetables, different methods of packaging materials like corrugated cardboard boxes, various sizes of plastic trays, nylon sacks, wooden crates, polythene bags, woven palm baskets, etc are used mostly in developing countries to minimize post-harvest loss (Pokhrel, 2021). Some amount of ventilation must be provided for packaged fruits and vegetables to prevent physiological breakdown. There may be the development of off-flavor in the product if there is water repellent to carbon dioxide(co2), oxygen(o2), and water vapor inside the package, so proper care should be taken while packing for transportation to avoid bruising and damaged fruits (Yahaya and Mardiyya, 2019). There is still a large portion of farmers still depend on traditional methods of packaging though newer technologies and methods are executed every year for fruits and vegetables to minimize post-harvest loss.

2.5 Storage

Table 3: Recommended Temperature, Relative Humidity and Storage Days of Common Fruits (Rajapaksha et al., 2021)

Fruits	**Temperature (0C)**	**Relative humidity (%)**	**Storage life (days)**
Mango	13	90-95	14-21
Banana	13-15	90-95	14-21
Orange	0-9	85-90	56-84
Papaya	7-13	85-90	7-21
Pineapple	7-13	90-95	10-14
Avocado	3-13	85-90	14-56
Watermelon	10-15	90	14-21
Guava	5-10	90	14-21

Storage helps to extend the shelf life of fruits and vegetables ensuring a favourable environment to prevent from deterioration of the products until consumed by the consumers. Those crops that meet specific quality standards should be stored (undamaged, with an appropriate level of maturity). It reduces malnutrition for a certain period by controlling the rate of respiration, transpiration, disease infection, ripening, and undesirable biochemical changes ("Post Harvest Loss Management and

Quality Control of Fruits and Vegetables in Ethiopia for Securing Food and Nutrition – A Review," 2020). It reduces transpiration loss to avoid sprouting, elongation, rotting, greening, and toughening of certain fruits and vegetables (Rajapaksha et al., 2021). Storage rooms' relative humidity plays a vital role in keeping the quality of the fresh produce so as the rate of respiration in relation to the temperature. If the temperature is high there will be a high rate of respiration and more numbers of decay organisms(Yahaya and Mardiyya, 2019).

Table 4: Recommended Temperature, Relative Humidity and Storage Days of Some Vegetables (Yahaya and Mardiyya, 2019)

S.N.	Vegetables	Temperature (OC)	Relative humidity (%)	Storage life (weeks)
1	Pumpkin	1.7-11.6	70-75	24-36
2	Potato	3.0-4.4	85	34
3	Tomato (unripe)	8.9-10.0	85-90	4-5
4	Tomato (ripe)	7.2	90	1
5	Asparagus	0-0	95	3-5
6	Brinjal	10.0-11.10	92	2-3
7	Cabbage (early)	0.0-1.7	92-95	4-6
8	Cabbage (late)	0.0-1.7	92-95	12
9	Cauliflower	0.0-1.7	85-95	7
10	Onion (leaf)	0.0	90-95	2
11	Onion (bulb)	0.0	70-75	20-24

Reducing post-harvest loss is one of the main concerns for all growers. There are various ways of storing the product by maintaining quality and enhancing shelf life.

2.6 Cold Storage

In cold storage temperature above the optimum will reduce the storage life and chilling injury is caused by lower temperature thus, the cold storage temperature should be maintained at the desired level for fruits and vegetables (Rajapaksha et al., 2021).

2.7 Zero Energy Cool Chamber

In zero energy cool chamber, there is no operation of electrical and mechanical energy as it works on the principle of evaporative cooling for the functioning of storage where there is the removal of latent heat from the surface and there is a reduction in temperature from which evaporation takes place.

2.8 Controlled Atmospheric Storage (CAS)

Controlled atmospheric storage helps to monitor and adjust oxygen, carbon dioxide, and carbon monoxide gases within the storage at an appropriate level as required to increase the shelf life of fruits and vegetables (Rama and Narasimham, 1978).

2.9 Modified Atmospheric Storage (MAS)

Modified atmospheric storage is the replacement of air that contains 21%O2, 78%N2, 0.03%co2, and traces of other gases which controls the pathogenic growth of fruits and vegetables reducing the post-harvest loss ("Post Harvest Loss Management and Quality Control of Fruits and Vegetables in Ethiopia for Securing Food and Nutrition – A Review," 2020).

2.10 Marketing

Marketing is the final stage of post-harvest practices where the product is sold by the producer to the consumer by various means. Fruits and vegetables are highly perishable in nature and they need extra care in providing time, place, and form which adds to overall marketing costs (Nayak, 2021). The fruits and vegetables are sold by farm gate selling, direct selling, or selling through the middle man where farm gate selling refers to those people who go to the farm and buy the produce from the farm only, direct selling can be understood as after general grading farmers sell their produces by carrying in the bamboo basket or doko or any kind of sacks on foot in the nearby market and selling through middle man is widely practiced, as large volume of products are collected by middle man and sells it by bringing to the retailer and to the consumers at the market place (Bhattarai, 2018). Many growers place their fruits on top of each other making a huge pile which leads to the generation of heat at the bottom and spoils the fruits. Condensation takes place which encourages mold to grow on the surface of fruits and the major problem is rejected, decayed produce is mixed with healthy produce in the same package (Kereth et al., 2013). According to the research paper, the major post-harvest loss of fruits and vegetables is that they are marketed on sun-exposed roadsides, lack of trading institutions to safeguard the rights of farmers, inappropriate market and pricing system, lack of knowledge about the marketing system to the growers and the large number of intermediaries in the marketing system (Ahmad et al., 2021). Handling and transporting are linked with marketing so a proper transporting system is used which directly increases the shelf life and enhances the market price reducing post-harvest loss.

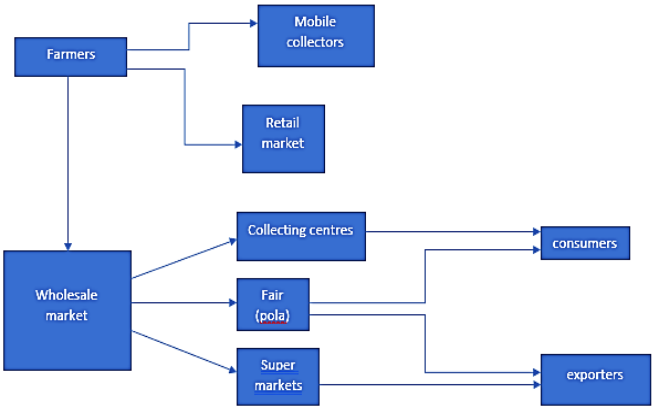

Figure 2: Schematic representation of supply chain of vegetables and fruits in general scenario

3. Conclusion

Fruits and vegetables are highly perishable in nature as compared to other agricultural crops. Minimizing post-harvest loss is really challenging as there is a loss in every step of post-harvest practices. Careful consideration should be done while harvesting, pre-cooling, cleaning, sorting and grading, packaging, storing, and marketing. There are other many methods to reduce post-harvest losses which include storing at lower temperature and controlling pathogens by post-harvest treatments on fresh fruits and vegetables. Talking about the economic criteria, there is a lack of marketing strategies, many farmers are exploited by the middleman, and lack of awareness about pricing policy. As compared to the old days, these days growers are at least adopting easy and new methods like, people used to carry bamboo baskets to sell their products in nearby markets but today there are adopting a by-cycle for selling their products which is good. Reviewing this article, there is a huge demand for fruits and vegetables but due to post-harvest losses, only suppliers are minimized.

Off-season vegetables and fruits are too high in demand as people tend to enjoy every season of fruits and vegetables as per their needs. If there is the proper handling of post-harvest practices and proper care of the procedure at every step then there will be a reduction in post-harvest losses. There are many technologies designed to prevent post-harvest loss reducing the risk of farmers but from a farmer's perspective, they have no direct experience with technology and may not understand it's benefits fully, such investment is too risky for the farmers. As loss cannot be totally minimized but it can be controlled or maintained so, there needs to be adoption of many other technologies, experience them to overcome the post-harvest loss of fruits and vegetables, until and unless losses will be the major challenges in upcoming days for developing countries like Nepal. Developing countries should give efforts to address post-harvest loss to focus on entire value chain rather than focusing on losses at a single stage.

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