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Post Harvest Management of Vegetables: A Review

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ABSTRACT

Horticulture is backbone of our country and greater population about 60-65% is directly or indirectly hooked in to it. In the export earnings for the country the role of horticultural produce is vital. In Indiaabout 20-40% of total horticulture produce wasted due to lack of post-harvest management of vegetables which resulted in huge financial loss. Most poor horticulture producers cannot meet the expense of modern technologies.Many metabolic changes occur in vegetables after harvesting that are influenced by disruption of supply of nutrients, water and growth regulators from the parent plant to the harvested vegetables. The overall process leads to postharvest deterioration of the produce. However, the losses are often reduced with adoption of postharvest management and use of processing technology of vegetable crops.

Key words: Horticulture, Post harvest, Processing, Vegetable.

Fruits and vegetables account for nearly 90% of total horticulture production in the country. India is second largest producer of vegetables in the world. Unfortunately, having such a huge production a considerable postharvest loss to the tune of 10-25% of vegetables (Selvakumar, 2014) occurs annually mainly due to inefficient postharvest management practices. Increase in production of vegetable as per the requirement of growing population, suppliesfor processing industry and export trade will not be sufficient if we have not focused on reduction on post harvest losses. India is also a prominent exporter of processed vegetables to the world. The country has exported 2,48,121.88 MT of processed vegetables to the world for the worth of Rs. 2,473.99 crores/354.65 USD Millions during the year 2018-19 (Anonymous, 2019). In order to maintain supply chain system, post harvest management is therefore need of the hour to feed growing population of country.

The term postharvest lossesthatincludes quality and quantity losses are defined as losses that occur after harvest till the produce reaches consumers. Post-harvest losses also generate financial losses in terms of expenditure on labor, transport and other charges. Quality losses include those that affect the nutrient/caloric composition, the acceptability and the edibility of a given product. These losses are generally more common in developed countries (Kader, 2002). Quantity losses refer to those that result in the loss of the amount of a product. Loss of quantity is more common in developing countries (Kitinoja and Gorny, 2010).

Vegetables are highly perishable having moisture content of (80-90%). They are live commodities and continue their life processes like respiration and transpiration even after harvest. When the fruit is attached to the parent plant, water and photosynthates are supplied to it. But losses are not replaced during postharvest stage and hence the produce depends on its own food reserve and moisture content with the result they perish fast. Water is lost from the product due to transpiration and food reserve depleted by respiration. Table 1 depicts post-harvest losses in different vegetablecrops. Factors which are responsible for post-harvest losses vary widely from place to place and become more and more complex.

Post harvest losses in food production to consumption value chain have a cause of great concern in enhancing the food availability for domestic as well as export purpose.

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Factors affecting post-harvest losses

Generally, post-harvest losses of vegetables are influence by many factors. These factors include losses due to physical, physiological, mechanical and hygienic conditions. Vegetables are mainly characterized by high level metabolic activities with short shelf life. As a result of these factors, substantial percentage of loss occurs between harvesting to consumption of the produce (Hayatu, 2000: Sani and Alao, 2006). In addition, other factors such as insect and mite injury, diseases which occur due to non-infectious pathogens and pathological rots also cause post-harvest loss of fruits and vegetables. However, among the causes, the pathological rots are the most serious which is followed by mechanical injury. Pathological rots in combination with mechanical damage cause serious damage to the perishables (Mustapha and Yahaya, 2006; Anonymous, 2011; William *et al.,* 1991). Environmental factors such as temperature, relative humidity and oxygen balance most especially during storage are also greatly responsible for damage also environmental conditions such as temperature and humidity are responsible for rendering fruits and

Table 1: Harvest and post harvest losses of vegetable crops.

Crop name	% average loss (Nanda *et al.,* 2012)	% average loss (Jha *et al.,* 2015)
Onion	7.5	8.20
Tomato	13.0	12.44
Cabbage	6.9	9.37
Cauliflower	6.9	9.56
Green pea	10.3	7.45
Potato	9.0	7.32
Tapioca	9.8	4.58

vegetables susceptible for pathological attacks. However, the loss of fruits and vegetables due to physiological and biochemical damage are closely interrelated (Sani and Alao, 2006; William *et al*., 1991).

Control of post harvest losses

There are two approaches for reducing postharvest losses of vegetables. First approach is scientific in which Post-harvest loss in fruits and vegetables can be decreased byadopting proper cultural operations, harvesting, transportation, storage and pre and post- harvest treatments. Second approach is processing it into value added products that helps to utilize maximum crops in a nutritious and safe manner. These are briefly discussed here.

Varieties with long shelf life

The selection of an adequate-yielding tomato cultivar with desired fruit qualities and longer shelf life is a important decision a producer must take. Some varieties with long shelf life like; Arka Vishal, Pusa Gaurav and TH-1 (Tomato), Arka Nidhi, Arka Neelakanth (Brinjal), PRO-6 (Onion) and MH-27 (Musk melon) should be preferred. These are also preferred due to good keeping and processing quality.

Harvesting

Consumers always prefer fresh, properly matured, insect and disease free fruits and vegetables of attractive appearance (Hayatu, 2000). Therefore, vegetables should be harvested at proper stage when they attain good colour and maximum size and yet are tender. Moneruzzaman *et al.* (2009) and Cliff *et al.* (2009) suggested tomato fruits can be harvested at mature green to give producers enough time for long distance marketing but for local marketing harvesting at the fully ripe stage is preferred to maximize nutritional value. Harvesting should be done at proper stage otherwise over maturity in root crops like carrot and radish consequences in pithiness and sponginess and therefore, their harvesting should not be delayed. However, the delayed harvesting in onion and garlic reduces their shelf life. Best time for the harvesting of vegetables is in early morning or late evening hours. A temperature of above 27°C during harvesting should be avoided and after harvest the produce should immediately be shifted to the packing shed. Mainly evening harvested vegetables are to be send to far-away markets and transported in the cool hours of night whereas commodities for local markets are harvested early morning. Care must be taken to avoid mechanical injury to product. Buckets, sacks, baskets and boxes are used to collect harvested vegetable from the field to a collection point, but most of these containers are poorly designed, inadequately maintained and unsuitable for the harvesting and transportation of the fresh produce. Therefore, in order to ensure good quality, the container for collection of harvested produce should be designed in such a way that they do not cause any injury to the field operations; also a high standard of field hygiene should be maintained.

Washing and grading

Fruits and vegetables need good handling before they are packed for transportation. Produce such as root and tuber crops are often washed to remove the soils adhering over them. Fruits and vegetables which have been treated with poisonous chemicals require very good washing before their packing. Washing with clean water prevent wilting and also improves the appearance of fruits and vegetables (Alao, 2000; Hayatu, 2000). Therefore, for good and effective marketing strategies, grading is an important component which should not be neglected. The produce is therefore, sorted into various grades and attractive forms which will attract good price for the produce (Alao, 2000; Hayatu, 2000). Sometimes fruits and vegetables are graded on the basis of shape, size and colour. While fruits and vegetables such as okra, cucumber, ridge gourd may also be graded on the basis of their maturity, ripeness in tomato fruits and general appearance. Therefore, during sorting of vegetables, all the characters that influence quality and appearance should be considered (Opadokum, 1987).

Trimming

In addition, it is important to trim vegetables such as cabbage, spinach and lettuce before they are harvested for the market (Alao, 2000; Hayatu, 2000). Trimming is done to remove unwanted, discolored, rotten and damaged parts. Trimming enhances visual quality, reduces deterioration of produce facilitates handling, packaging and transport.

Curing

Curing roots and tuber crops such as potatoes, onion, sweet potatoes, cassava and yams is an important practice if these crops are to be stored for some time. Curing is a normal practice after potato harvested to promote dormancy and extend postharvest storage life, by preventing decay caused by microorganism during storage (Hide and Cayley, 1983, 1987). Curing is accomplished by holding the produce at high temperature and high relative humidity for several days after harvesting with the objective to heal the wounds and form a new protective layer of cells. While curing can be initially costly, the extended length of storage life makes the practice economically worthwhile. Potato curing is most effective at about 20°C and 80% relative humidity. Nega *et al.* (2015) observed that combination of curing bulbs for 10 days and none topped bulbs was

the best practice to prolong shelf life of onion. The curing techniques like neck cut in onion bulbs and exposure to onion bulbs in gamma radiation for storage are proved to be useful techniques in delaying sprouting and their subsequent deterioration resulting in improved shelf life (Anbukkarasi *et al.,* 2013).

Waxing

Objective of thewaxingisto minimize water loss, reduce shriveling and enhance appearance. Stem near the petiole and pores on the surface of fruits which are the main routes of transpiration is sealed by the application of wax. Paraffin wax, Carnauba wax and various resins are common types of wax used for preparation of wax emulsion. Waxes are generally preceded by: foaming, spraying and brushing and, among all foaming is the best, as it leaves a very thin coating. Some of the common coating materials are simper fresh, prolong and waxed. Vegetables like tomato, brinjal, sweet pepper, cucumber, muskmelon, carrot are often waxed. High temperatures increase the rate of respiration and hence deterioration. Once harvested, exposure of the vegetables to the sun causes shriveling and rapid quality deterioration. Vegetables like brinjal, tomato, cucumber, muskmelon, carrot etc. are frequently waxed with a water emulsion by dipping or spraying to slow down the moisture loss from the product and at the same time to improve their shine. This practice of keeping the product sound and lustrous is generally not in vogue in our country.

Precooling

Pre-cooling is a vital post-harvest management practice required prior to storage. While there is a huge difference among the temperature of harvested crops and cooling system of transport or storage, the main function of pre-cooling is to eliminate the field heat from the crops after harvesting. High temperatures increase the rate of respiration and hence deterioration accordingly, pre-cooling helps in reducing fruit respiration rate and extends crop storage life. On the other hand, pre-cooling also inhibits the growth of various microorganisms, thus reducing the possibility of post-harvest diseases. The success of pre-cooling will depend upon two important factors; the time between the harvest and pre-cooling and initial crop temperature before pre-cooling. Mostly, it is recommended to perform pre-cooling justafter the harvesting. Generally, one hour of delay between harvesting the tomato crop and cooling it will lead to one day loss of shelf life (Cantwell, 1999 and Paull, 1999). Furthermore, there are some crops that can be successfully stored without pre-cooling. These include cabbage, cauliflower and radish.

There are several methods of pre-cooling process as follow.

(a) Room cooling

A simple pre-cooling practice that includes placing the crops in a refrigerated room or container. Although the practice has relatively low energy requirements, it's very slow and therefore recommended for crops that decay slowly.

(b) Forced air cooling

Removes field heat by using fans that circulate cool air throughout the storage chamber at high speed. This method is effective for pre-cooling of already packed berries and stone fruits.

(c) Hydro-cooling

One of the most common and effective pre-cooling methods. The method includes spraying or immersing the crops into cold water. One more advantage of hydro-cooling is that it also cleans the crop. However, various pathogens can be spread by water. Therefore, hydro-cooling requires adequate water quality and sanitation management. For this purpose, some farmers use chemicals to prevent the occurrence of bacterial or fungal diseases.

(d) Vacuum cooling

A method in which air is drawn out of the chamber. That way, pressure allows evaporation of crop moisture. Since the high amount of heat is required for water evaporation, this method is the fastest way of pre-cooling. This method is highly effective for leafy vegetables. In addition to vacuum cooling, farmers can also add water spraying in order to speed up the process of reducing thermal energy in the crops.

(e) Ice cooling

A method that includes applying crushed or granulated ice into a storage container or a box. As the ice melts, the cool water reduces the heat of the crops. The method is mainly used during the crop transport.

Post- harvest disease control

In vegetables, mainly postharvest diseases are caused by infections through fungi and bacteria. The majority of fungi grow in an acid (pH 2.5-6.0) environment and develop whereas bacteria flourish best in neutral conditions and only a small number of species can grow at levels below pH 4.5. Bacteria therefore normally only infect vegetables and not fruit, which are too acidic. Various types of injuries in produce can be continued before and after the harvest. Mostly Injuries caused by; insects, birds, rodents, weather and farm equipment. Injuries usually occur by dropping produce on the hard surface in field, during packing and after packing, but injury is not frequently noticeable immediately. Soon after, bruising may also take place, but it is evident only on peeling like in potatoes. The damaged produce is attacked by various microorganisms, resulting in a progressive decay, which may affect the entire produce (Snowdon, 1990). Post-harvest diseases can be controlled by use fungicides as sprays or dips, incorporated in wax or impregnated in packaging.

Sprout inhibition

Tuber and bulb crops (onion and potato) enter a dormant stage at maturity, sprouting starts at the end of dormancy or rest period. Sprouting is a growth resumption process. Sprouting causes huge loss due to respiratory utilization of substrates. Maleic Hydrazide (MH-40), 3-Cholorisopropyly-

N-Phynle Carbamate (CIPC), Methyl Naphthalene Acetic Acid (MENA) and 2,3,4,6 Tetra Nitro Benzene (TCNB) are commonly used as sprout inhibitors (Kleinkopf *et al*., 2003). Gamma irradiation at 0.02- 0.15 KGY is widely accepted by many countries for successful sprout inhibition of onion and potato without affecting other quality attributes.

Packaging

Packaging is most important to maintain the quality of highly perishable products. The major role of packaging is; to accumulate the produce into convenient units for handling and protect the produce during distribution, storage and marketing. Selection of the packaging materials is done on the basis of plant characteristics. It enhances the storage life of product as well as provides greater attraction to the produce. A goodpackaging practicessafeguard the product from; physical injury, physiological and pathological deterioration during transport and storage. Mostly bamboo baskets, plastic crates and gunny bagsare used for packaging purposes of horticultural produce. (Nasrin *et al*., 2008) conducted a study on shelf life and quality of tomato and confirmed that tomato treated with chlorine; packed in perforated (0.25%) polyethylene bag and kept at ambient temperature (20-25°C) and relative humidity (70-90%) condition resulted in substantial reduction in decay and weight losses. The same treatment combination also considerably delayed compositional changes in TSS, total sugar, reducing sugar, vitamin-C, β-carotene, *etc.* Under this condition, shelf life of tomato extended upto 17days as compared to non-treated and kept in ambient condition without packaging or packed in gunny bag for 7 days only. Serrano *et al.* (2006) packaged broccoli heads using 3 types of polypropylene films; macro-perforated, micro perforated and non-perforated and then stored at 1°C for 28 days and observed that, especially for micro perforated and non-perforated films, all changes related with loss of quality were significantly reduced and delayed with time. Increasing CO_2 seems to be more effective than decreasing O_2, Broccoli maintains its quality longer in both perforated and sealed polyethylene packages than did non-packaged controls (Granado-Lorencio *et al.,* 2008).

Transport

Transport is an important linkage in postharvest handling, storage and distribution. Mostly, fresh horticultural produce is now distributed to the markets by road vehicles, with smaller amounts through ship, air or inlandwaterways. Severe losses take place during transportation due to; careless loading, improper handling, unloading and by using improper containers. During transportation of fresh produce during cool hours of night, vehicles opted proper ventilation, insulated evaporative cooled or refrigerated ensures preservation of quality. Refrigerated preservation of foods is based on the principle in which we can reduce and maintain the temperature of the food sequentially to control, decrease or stop the rate of deterioration of food. In many countries, Pallets are used for trading of horticultural produce. It is also important to work for mechanical loading as well as unloading mainly with the utilization of fork lift trucks. In India use of containers working on evaporative cooling techniques should be encouraged.

Marketing system

Vegetable market is often suffering from several constraints due to their high perishable nature, seasonal marketing and bulky nature. Assembling and subsequent marketing of the produce is further blocked due to lack of proper storage facilities and quick transport systems. Very often the products are formed to dispose of their produce at a very nominal price where there arisesseasonal gluts due to these bottlenecks. Another major defect in vegetable marketing is that the involvement of several intermediaries which dominate the trade and obtain huge profit. Consequently producers margin in the consumer price becomes very low. It is therefore essential that planned effort for establishing co-operative system of selling should be enforced at village and district levels to manage activity of intermediaries and to regulate the vegetable marketing smoothly and during a streamlined system. Moreover, close co-ordination among Agricultural Marketing Board, National Horticulture Board and State Department of Agriculture/ Horticulture should be ensured to formulate an action plan for regulating marketing of vegetables in a smooth and streamlined way. Abubakari Mutari and Rees Debbie (2011) reported that due to rough handling of tomatoes destructed the fruit cell wall leading to softening and reduced marketability of the produce. Also, high storage temperature can result in increased respiration (3.8 mlCO_2/kg-h) and ethylene production (7.85 µl/kg/h) significantly as well as accelerate ripening (16.80) and weight loss (97.08%). Therefore these conditions (rough handling and high temperature) accelerate the metabolic rate of tomatoes and there by reduce the shelf life of the produce.

Storage

Storage of vegetable plays an important role for improving shelf life by avoiding market shortage and to ensure supply throughout the year that result an increase a good profit to the producers. Abubakari Mutari and Rees Debbie also (2011) studied that high storage temperature resulted an increased in respiration and ethylene production significantly accelerated ripening and reduced weight loss. Therefore these conditions (rough handling and high temperature) accelerate the metabolic rate of tomatoes and thereby, reduce the shelf life of the produce. The principle aim of storage is to decrease and control transpiration, respiration and disease infection at the same time maintaining life processes at the required level. Different methods of storage of vegetable produce are as:-

(a) Refrigerated storage

Refrigeration is one of the most effective methods of preserving the quality of many fruits and vegetables for several days (Batu *et al*., 1998; Rodriguez *et al*., 2001).

Low temperature storage can protect nonappearance quality attributes like texture, nutrition, aroma and flavour in many harvested fruits (Paull, 1999). Highly perishable vegetable produce requires Refrigerated vegetable storage. It retards the rate of metabolic change, moisture loss, respiratory heat production and spoilage (caused by heat production or micro-organisms) and thereby enhances retaining life of vegetable produce.

(b) Controlled/modified atmosphere

The main purpose of controlled atmosphere (CA) or modified atmosphere is to adjust the atmosphere composition of gases surrounding the commodity by removal or addition of gases. Thus resulting in an atmospheric composition different from that of normal air. Modified atmosphere does not differ in principle from the controlled atmosphere storage except that the control of gas concentris less precise.

(c) Hypobaric storage

Hypobaric storage is similar to controlled atmosphere storage in which produce is stored in partial vacuum. The vacuum is created by vacuum pump to a particular desired low pressure. The process of ripening and senescence is greatly reduced by decreasing rate of respiration and removal of ethylene.

(d) Zero-energy cool chamber

In tropical areas like India, tremendous amount of quality deterioration take place immediately after harvest of produce due to lack of on farm storage facilities.To overcome this problem, low cost environmental friendly zero energy cool chambers are developed by IARI New Delhi, these chambers work on principle of evaporative cooling using locally available materials like brick, sand and bamboos. The temperatures in these chambers are less than surrounding atmosphere. These chambers can be used for short term storage of products at the farmers field itself.

Postharvest loss is more serious as compared to production loss. Reduction of postharvest losses significantly increase availability of vegetables without bringing additional land into production and without using additional inputs. Although losses cannot be reduced completely, but can be minimized by adoption of modern cultural practices, harvesting, handling, marketing and processing techniques.

Processing in vegetables

Postharvest loss in quality as well as quantity of fruits and vegetables is huge due to seasonal production, high perishability, shorter shelf life and preservation through processing is one of the best methods to minimize the loss (Archana *et al*., 2020). Processing industry of horticulture crops including vegetable crops is a very backbone of horticulture industry taking care of gluts and wastes. Processing can fetch an additional income to the grower's and helps in stabilizing the prices with economic returns. The best indicator of the economic contribution of food processing to the food system is the value addition. Value addition is the indicator of the industry's contribution to GDP.

CONCLUSION

In conclusion, Postharvest handling of vegetables is the final stage in the process of producing high quality fresh produce. In order to sustain a level of freshness from the field to the dinner table presents many challenges. A grower, who can meet these challenges, will be able to expand his or her marketing opportunities and be better able to compete in the marketplace.

Conflict of Interest

All authors declare that they have no conflict of interest.

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