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Postharvest Technology of Fruits and Vegetables: An Overview

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Abstract

Harvested fruits and vegetables require adequate and advanced postharvest processing technologies for minimizing the qualitative as well as quantitative losses after harvesting. Nearly 40% fruits and vegetables are wasted every year due to improper handling, storage, packaging, and transportation. Wastage of fruits and vegetables in huge amount due to un-implementation of advance postharvest technological approaches also reduces the per capita availability of fruits and vegetables. Intensive emphasis is required to develop the advance postharvest technologies for improving the global food security by enriching the economy of agricultural produce of the world with minimal losses of consumable fruits and vegetables. The present article discusses the common yet important postharvest technologies to maintain the quality of fruits and vegetables.

INTRODUCTION

Total vegetable and fruit production in the world has been estimated 486 million and 392 million tons, respectively and 30-40% of total production in developed country is spoiled due to lack of postharvest handling up to consumption. India is second largest producer of fruits and vegetables with first rank in production of ginger and okra, second in bananas, papayas, mangoes etc. (Anonymous, 2013). But in the case of developing country like India, the postharvest losses noticed close to 50% of the total fruits and vegetables production which badly affects the availability of fruits and vegetables to the consumers (Sudheer et al., 2007). Perishable fruits and vegetables (fruits and vegetables with more water content) facilitate the easy attack of the micro-organism due to high water activity and spoiled rapidly. Improper handling, storage, preservation techniques and microorganism spoilage increase the postharvest losses in fruits and vegetables up to 40%. The microbial effect plays a vital role in spoilage of fruits and vegetables due to some extensive heat or cold resistance micro-organism the processed or canned product also can be damage (Sharma et al., 2013).

Practices of postharvest technologies can reduce the quantitative and qualitative losses of fresh fruits and vegetables and also maintained the product quality up to final consumption. Attaining the hygienic agricultural produce should be focused on the varieties of higher postharvest longevity (Wasala et al., 2014). Postharvest produce require appropriate handling and

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transporting facilities. Several studies concluded that postharvest losses are still a challenge and no significant declination has been observed within past two decades according to the resources (educational programs, training programs and research programs) utilized. Intensive study reveals that total postharvest losses (during harvesting, handling, packaging and transporting) lies between 30 to 40% of the total production. Review of many literatures also concluded the several hygienic and disinfected postharvest technologies are developed but evaluation of feasibility and financial benefits of the mentioned postharvest technologies to the producers has not been documented properly (Kitinoja et al., 2011). Postharvest quality and shelf life of the fruits and vegetables related with the cultivation practices, varieties of the cultivar and environmental aspects. The soil and climatic characteristics and integrated management practices also affect the postharvest losses and postharvest storage duration (Bachmann et al., 2000). Due to high water activity, fruits and vegetables are considered more perishable and nearly 33% of total produced fruits and vegetables have been spoiled during harvesting to marketing (Kader, 2005). Salami et al. (2010) stated that total 30-40% fruits and vegetables wastage occurred within harvesting to consumption. In the case of developed and developing countries, the losses of fruits and vegetables estimated around 5-30% and 20-50% respectively (Kader, 2002). Reduction in the quality, storage duration and shelf life can be minimized with the help of adequate storage, transportation and environment conditions (Ilić et al., 2009). Several environment factors like temperature, humidity and gaseous atmosphere are responsible for postharvest losses. Different fruits and vegetables treated as an important source of vitamins, minerals and fibre due to the several nutritional benefits the consumption of fruits and vegetables increased which also improve the commercialization of fruits and vegetables (Egharevba, 1995).

POSTHARVEST LOSSES: WORLD SCENARIO

Minimization of postharvest losses from harvest to consumption depends upon the several biological, environmental aspects, which can be controlled with the use of appropriate postharvest technology. Several quality factors like nutritional value, physical appearance, and sensory characteristics affect the quantitative as well as qualitative losses of fruits and vegetables. Some research stated that there were huge differences between postharvest losses of developing and developed countries, estimated range of losses 2-23% varies depends on different produces in united states (US), simultaneously overall average losses from production till consumption was estimated 12% (Harvey, 1978). In the case of developed countries the range of losses was observed 10-50% (Kantor et al., 1997). Researchers have noticed that 20% fruits and vegetables wastage estimated as a consumer and food service losses (Kader, 2005). In Rwanda, Ghana, Benin and India, recent studies have generated similar findings, with losses ranging from 30% to 80% (Kitinoja et al., 2011). Postharvest losses depends upon the various significant factors after harvesting till consumption that is why estimation of exact losses value is difficult which required statistical methods for found out the accurate figure of postharvest losses, first statistical survey based on successive sample technique was conducted in Uttar Pradesh, India with the help of Indian Agricultural Statistics Research Institute. The sampling design used in the survey was based on successive sampling technique (Gupta et al., 2000). Total 1.30 billion tons of consumable food commodities spoiled per year caused the huge gap between total per capita production and per capita availability of the food commodities. Minimizing the losses directly influence the availability of food and improves the global food security. Economy of the farming based regions of the world affected with the postharvest losses because the in this regions selling of the fruits and vegetables have major source of income. Livelihood of nearly 70% of the Sub -Sahara African countries depends upon the fruits and vegetables**.**

Wastage of significant part of fruits and vegetables not only caused the scarcity of the consumable food products but also create the extra concern towards the waste-deposition, Gasses evolves during degradation of spoiled food etc. Anaerobic decomposition of waste or spoiled fruits and vegetables in the soil emits the methane gas and pollutes the environment (Buzby and Hyman, 2012). 31 million metric tons food were spoiled and produced 14% of total solid waste of the country in 2008 reported by United state environmental protection agency and total cost of underground decomposition was noticed 1.3 billion dollars (Buzby and Hyman, 2012).

POSTHARVEST LOSSES: INDIAN SCENARIO

India is a major fruit and vegetable producer country of the world with 32 and 71 million metric tonnes respectively. Productivity of the fruit varies within 4-35 tonnes per hectare and productivity of vegetables varies within 6-15 tonnes per hectare. India produced 8% and 15% of the total world fruits and vegetables production respectively. After China, India is the world largest producer of total fruits and vegetables in the entire world but due to unavailability of appropriate cold storage, refrigerated transportation facilities, the fruits and vegetables of Rs. 13300 crores spoiled every year (Bhosale, 2013). Diversified climate of the India helps to produce most of all varieties of fruits and vegetables. In the different steps of postharvest handling nearly 20-30% of the produced fruits of the total produced vegetables were spoiled and decreased the 100 g (Based on total produced fruits) to 80 g per capita per day (based on consumable produces after losses reduction). Production rate of the fruits increases with 3.9% annually and processing sector involves for the fruits strengthen 20% per year. In the case of vegetables 30-35% of the total produced vegetables were lost and only 2% of the total produced vegetables undergone for processing and able to marketed only 0.15 million tons of processed vegetables (Anonymous, 2006). Export market of vegetable also expanded and noticed 16% in volume and 25% in value of the total produced vegetables. Generally, India exported the vegetables to the Asian Region (Sri Lanka, Malaysia, Gulf countries and Singapore) and Europe (United Kingdom).

FACTORS CONTRIBUTING TO TOTAL FOOD LOSS

Several factors and adopted technologies play vital role in postharvest losses of the different fruits and vegetables like harvesting methods, handling, transportation facilities, preservation techniques and market availability. With the help of modern techniques and approaches, developed countries have minimize the postharvest losses up to some extent but due to less mechanized methods, developing countries are still facing a big challenge (Hodges et al., 2011). Total consumable food losses have been estimated of 4 billion dollar which sufficient for feeding the 48 million peoples in Sub-Saharan Africa. Significant degradation in quality and quantity of fruits and vegetables within harvesting to consumption considered as postharvest losses (Hodges et al., 2011). Deterioration in the weight, volume considered under the quantitative and losses of nutrient value, color, texture defined as the qualitative losses (Buzby and Hyman, 2012). Due to unavailability of suitable harvesting equipment, storage structure for storing the fruits and vegetables, hygienic packaging and appropriate transportation facilities caused the major deterioration in fruits and vegetables (Anonymous, 2006). The transportation of perishables agricultural commodities with the help of road transported vehicles hamper the quality of commodities and basically caused the significant textural damages (higher in the case of perishable commodities) due to the irregular and unsmooth roads (Jones et al., 1991). Singh and Singh (1992) has been stated that the different fruits and vegetables absorbs vibration and collapsed with each-other during road transportation, handling, loading and unloading which caused mechanical damage. Different types of citrus fruits contains different amount of vitamin C and minerals, which can be lost in high temperature storage (Lee et al., 2000).

STEPS FOLLOWED AFTER HARVESTING

Availability of perishable produces up to long time after harvesting is possible only with skilled and scientific processing approaches to preserve the products with least deterioration.

Postharvest Handling

Fruits and vegetables should be harvested very carefully after observing the appropriate maturity level and quality because lower or upper maturity level of produces reduces the storage life and enhanced the spoilage (Siddiqui et al., 2014; Ahmad et al., 2014). Single bruising of apple increased the moisture losses up to 400% (Bachmann et al., 2000). Good methods of harvesting, handling, transportation and storage enlarged the shelf life and maintained the qualitative characteristics of the harvested produces. Sterilized or properly clean packaging also helps for enhance the quality and prevent the excess respiration of packed fruits and vegetables. Several preservation technologies like cold storage, modified atmosphere packaging and edible coating has been used for keeping the fruits and vegetables safe and hygiene.

Cooling of the harvested fruits and vegetables

Good quality of the fruits and vegetables depends upon temperature because storage at optimum temperature retards over ripening, softening, respiration rate and spoilage (Bachmann et al., 2000). Bachmann et al. (2000) stated that higher storage temperature increased the respiration rate results rapid spoilage and fast degradation in shelf life of the fruits and vegetables. Absorption of the heat via surrounding temperature causes the high respiration and successive deterioration of the fresh products. Pre-cooling decreases the temperature up to requisite level before processing or storage and retards the chemical and changes of fruits and vegetables during processing or storage (Wijewardane, 2014). Shelf life of fruits and vegetables has been increased with the help of different pre-cooling methods. Research stated that for maintaining the temperature of previously cooled fruits and vegetables the room cooling is suitable, for storing the packed produces the forced convection method were found to be suitable because its remove the heat 75-90% faster than room cooling. Simultaneously cleaning and cooling of the fruits and vegetables named as hydro cooing considered as efficient method of cooing as well as reduce the temperature five times faster than air. Dense kept and high respiration agriculture produces (like sweet corn and broccoli) were cooled with top or liquid icing. Research has found that 0.453 kg of ice decreased the temperature of 1.36 kg fruits and vegetables from 85^0F to 40^0 F. Generally, for decreasing the temperature of leafy fruits and vegetables the vacuum cooling was preferred because with the help of this method the heat removal from the tissues takes place with the application of vacuum pressure (Bachmann et al., 2000). Fresh and hygienic characteristics of the fruits and vegetables maintained with the help of adequate cooling system during storage. Refrigeration is one of the most frequently used cooling methods and cold chain (Supply chain of fruits and vegetables with controlled temperature) also practiced for minimizing the losses throughout the entire storage and distribution system (Ilić and Vukosavljević, 2010). According to the physical and chemical properties, the freezing temperature of different consumable commodities varies and maintained the initial frozen temperature between -10 to -40 ^{0}C (Shah et. al., 2000). Cooling of fruits and vegetables is necessary at different stages like after harvesting (pre cooling), during storage (cold storage) and during transportation (vehicles with freezer) for controlling the wastage and degradation in the quality aspects of the produces**.** The numbers and capacity of cold storage increased in India during last few years but still not sufficient for handling the production and the existed cold storage also need to be improvement (Yahia, 2010). Mazza (1983) studied that appropriate controlled of storage temperature up to 7^{0}C minimize the respiration rate, excess moisture loss and textural shrinkage which reduce the weight loss of the potatoes and prevention of browning also focused (because of potatoes contains reducing sugars) during long storage (8-10 months) period (Kibar, 2012). Commodities condition, packaging process, and storage system of the agricultural products are affected by implemented cooling methods. Different kinds of cooling like room cooling, hydro cooling and forced air cooling have been used in which room cooling decreased the temperature of the produces slowly in the comparison of hydro cooling as well as forced air cooling.

Postharvest storage

Research concluded that 10-12^{0}C temperature and 90-95% relative humidity required for storage of cucumber because low temperature less than10^{0}C enhances the chance of chilling injury and above 16 degree colour of cucumber turned to yellow and accelerate more rapidly in the case of multi fruits and vegetables was stored at same place (Tan, 1997). Storage facilities affect the physiochemical quality of fruits and proper care of maturity level of the fruits and vegetables in the storage minimized the decay, percentage and total sugar level. Some research revealed that maturity affects the many quality parameters of the fruits and vegetables like weight, shelf life and bioactive molecules contents (Siddiqui et al., 2013a; Siddiqui et al., 2013b; Hossain et al., 1996). Botrel et al. (1993) studied the different ripening stages of the tomato also effect the pH value and concluded the maximum pH has been observed for matured green tomato. Total soluble solid content, total sugar content, weight and shelf life of the Mango fruits gradually increased with the increasing storage time (Roma et al., 2009). Uncontrolled temperature and humidity during storage increased the losses only can be controlled with the help of adequate refrigerated storage. Determination of postharvest characteristics of fruits and vegetables like colour, physical firmness, moisture content and sensory it is important to regulate the proper storage and transportation (Ahmad et al., 2014; Dadzie, 1997). Quantity of ascorbic acid decreases with increased duration of storage and temperature (Adisa, 1986). Content of ascorbic acid decreased nearly half of the original amount within 6 months of cold storage in the case of apples (Lee et al., 2000). Chakraverty (2001) studied that spoilage of fruits and vegetables depends upon the several factors which defined as intrinsic factors like oxidation-reduction capacity, maturity level, cultivar, nutrient level and some exterior factors like temperature of storage, handling of produces and availability of oxygen. If at the time of harvesting the fruits and vegetables are not so dirty then can be stored without washing because of more moisture addition enhanced the chance of spoilage and some fruits and vegetables are very dirty just after harvesting, for such types of produces must be washed and properly dry up to optimum moisture level before storage**.** Generally, the shelf life of fresh cut fruits or vegetables is less than the same without cutting as a whole and for preventing the vitamins and minerals losses the several fruits and vegetables needs appropriate temperature and relative humidity during storage (Abadias et al. 2008).

Shelf life and postharvest preservation temperature ranges were varies for different types of fruits and vegetables like some fruits and vegetables stored at temperature slightly more than freezing but some others fruits and vegetables store safely at 45-55^{0}F. Some fruits and vegetables like pumpkin, okra, sweet potatoes and cucumber are highly sensitive to chilling injury but same time tomatoes, watermelon, muskmelon and peppers have moderate chilling injuries (Bachmann et al., 2000). Chilling injury was a physiological disorder subjected to the subtropical and tropical fruits below the temperature 12-14^{0}C (Dadzie., 1997). Storage of fruits crops like banana, pineapple and sweet potatoes at low temperature hamper the quantity of ascorbic acid and accelerate the chilling injuries because of destruction in the ascorbic acid content caused the chilling (Miller and Heilman, 1952). The temperature of fruits and vegetables during entire processing influenced the ascorbic acid content and caused chilling injury. Amount of ascorbic acid reduced at the lower temperature (5^{0}C) but not affected at higher temperature (20°C) in the case of cucumber (Izumi et al. 1984). During the storage and preserving process of fruits and vegetables the moisture and relative humidity also affect the shelf life, quality and other characteristics because mostly fruits and vegetables has shown better quality aspects at higher relative humidity (80-95%) (Bachmann et al., 2000).

Packaging

Temperature is an important factor of postharvest processing and responsible for respiration and water activity of the fruits and vegetables. High temperature accelerate the respiration rate and spoiled the perishable fruits and vegetable rapidly due to high water activity in the comparison of the agriculture produces have less water activity.

Fruits and vegetables require good packaging, which can prevent the physical and chemical damage (Bachmann et al., 2000). Proper packaging and handling have been consider for preventing the mechanical damages of fruits and vegetables because more compact as well as loose packaging, un proper handling during loading and unloading caused the mechanical damages which affect the market value of the produces. Unsuitable packaging of fruits and vegetables increased the losses during handling and transportation that is why detail study of packaging technologies were required to overcoming from the losses of packaged fruits and vegetables (Idah, 2007). Shelf life of any product also enhanced with the help of modified atmospheric packaging by controlling the oxygen's and carbon-di-oxide levels within the packaged products (Yumbya et al., 2014). Modified atmospheric packaging is concept based on controlled atmosphere according to the desirability of the product longevity. The respiration rate of packed fruits and vegetables can be decreased with reduction in O_2 level with increasing the level of CO_2 (Beaudry et al., 1992).In this modern age for preserving the fruits and vegetables which have high moisture content (perishable product) and high respiration rate, several packaging techniques have been developed. Day (2008) found that for preserving the fresh fruits and vegetables up to long duration without deterioration of quality aspects the active packaging is most suitable.

Active packaging

Increased demand of fresh fruits and vegetables needs efficient packaging, which can restore the product quality up to long time (processing to consumption). Several intensive studies occurred for developing the advance packaging technique because controlling the fruits and vegetables deterioration with the help of traditional packaging technologies is impossible**.** Active packaging is very efficient and successfully used for packing the fresh fruits and vegetables and provides better packing characteristics at marginal cost (Mehyar et al., 2011)

Quality of the packed product cannot be efficiently maintained with general packaging technologies due to which a suitable and advanced packaging technique has been developed for controlling the deterioration and enhance the shelf life of fruits and vegetables by adding active ingredients in the packaging materials (Rooney, 2005). Active packaging is very useful for preserving the perishable fruits and vegetables because of this modern packaging technique, different types of indicators (colour indicators, oxygen indicators and CO_2 indicators etc.) also can be used for alarming the condition of packed products which facilitates the hygienic quality control (Rodrigues and Han, 2003). For reducing the postharvest losses packaging of fruits and vegetables must be as efficient as remains the freshness and quality attributes during commercialization and till consumption. Ozdemir and Floros (2004) stated that active packaging provides efficient barrier to the moisture and gasses migration, minimize the chances of contamination from outside and facilitate the handling process throughout the storage and marketing periods**.** Han and Floros (2007) studied that active packaging technique is the most suitable for packing of different fruits and vegetables because this type of packaging system worked as oxygen reducer (because availability of oxygen promotes the respiration and detonation of packed products), CO_2 producer (CO_2 kept raised the temperature of packed food and retard the growth of micro-organism), moisture controller (reduce the rapid deterioration of product) and also controls time and temperature with the help of indicators.

Perforated Films

Perforated films used for packing the fruits and vegetables and kept the product safe on the basis of the amount of escaped gasses via perforated layer as well as the gasses enters from polymeric film is balanced with the throughout gasses movement rate of perforated film (Fishman et al., 1996). In the case of perforated film packaging the cool air has been supplied for providing a suitable temperature to the packed fruits and vegetables (Sharp et al., 1993).

Modified Atmospheric Packaging

Mohamed et al. (1996) studied that shelf life of the product enhanced with the help of modified atmospheric packaging and noticed the qualitative packaging life of the fruits are 4 and 3 weeks for 10^0C and 15^0C, respectively, which shown better result than one week in the case of without modified atmospheric packaging. Reduction in ethylene production, retard the enzyme activity and improved the product quality of tomato with controlled oxygen level nearly 3% or CO_2 closed to 20% (Sozzi et al., 1999). Study reveals that combination of 6% oxygen and 14% CO_2 within the controlled atmosphere packaging prolong the shelf life of fresh cut pineapple up to 7 days at 10^0C (Chonchenchob et al., 2007). Storage of carrots at combination of 80%

oxygen and 10% CO_2 extended the shelf life better than storage at 5% oxygen level and maintained the better physiological properties of the carrots (Ayhan et al. 2008). Modification of packaging atmosphere performed after the intensive study related to the fruits and vegetables characteristics is necessary for achieving the better quality of particular packed products and more emphasized on elimination of the factors which responsible for high deterioration like for preventing the fruits and vegetables from microbial losses, the antimicrobial should be applied during packaging (Jong and Jongbloed, 2004). Different composition of gasses has been controlled with the help of advanced packaging technologies for preventing the deterioration and enlarging the shelf life of fruits and vegetables at controlled storage temperature (Argenta, 2004).

FUTURE APPROACH

World population growing up rapidly and expected to become 10.50 billion up to 2050 means demand of fruits and vegetables ramped up. Per capita availability of the fruits and vegetables has been increased with the reduction of postharvest losses. Kader and Rolle (2004) stated the 95% of the total research investment directed for enhancing the productivity and only 5% investment involved in postharvest losses reduction of the fruits and vegetables. Intense research needed for minimizing the postharvest losses because nearly half of the produced fruits and vegetables have spoiled. Very fewer resources were used for research and extension of postharvest processing of horticultural produces and the focus provided to the production enhancement during past 20 years (Kitinoja et al., 2011). Effective elimination of postharvest losses has been required strong communication and ideas exchange among farmers, postharvest engineers, food technologist, and specialist of market of fruits and vegetables because reduction in postharvest losses and extension in the shelf life possible with advanced research and application of new scientific approach (Kader, 2005). In a study, researcher have observed that the quality and product cost has been reduced with the aim of quick processing and money making that is why further more consumable products processing oriented research were essential for the obtaining high hygienic and economical product value (Ram et al., 2008).

CONCLUSIONS

Implementation of efficient postharvest processing technologies were able to minimized the losses of the fruits and vegetables and enhance the food availability which can reduce the scarcity of the agriculture produces among the consumers. Effective elimination of postharvest losses has been required strong communication and ideas exchange among farmers, postharvest engineers, food technologist, and specialist of market of fruits and vegetables because reduction in postharvest losses and extension in the shelf life possible with advanced research and application of new scientific approach. Maintenance of the physical appearance, flavour, market value and other characteristics of consumable commodities, the proper and scientific processing are required. More and more emphasis is required for minimizing the fruits and vegetables losses throughout the world for overcoming the scarcity of fruits and vegetables in any corner of the world. This would help to enhance the per capita availability of fruits and vegetables by applying intensive and modern technologies because of reduction in losses automatically increased the availability of products without applying extra resources for enhancing the production and productivity.

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