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# Post-harvest losses in different fresh produces and vegetables in Pakistan with particular focus on tomatoes

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**ABSTRACT**

**Purpose**: International agencies have advocated that monitoring food security and world food resources are necessary to meet the needs of growing populations and to minimize postharvest losses. This paper focuses on the biochemical and physiological bases of changes that causes post-harvest losses and ways to mitigate them. By controlling these metabolic changes, some degree of preservation is possible. **Findings:** Postharvest losses are 30-50% in developing countries due to energy crisis and lack of proper handling procedures and refrigeration; in contrast to less than 15% in developed countries. Highly perishable commodities like fruits and vegetables are living entities which are characterized by life evolving activities like respiration, transpiration, ripening and metabolic changes. Various compositional changes, such as chlorophyll degradation, softening, and ascorbic acid losses can result in short shelf life. Total 63 species of vegetables are grown in Pakistan but onions, potatoes, tomatoes, garlic, green chilies, coriander, spinach, pumpkin and okra are mostly grown and consumed. **Limitations**: In Pakistan due to energy crisis and economic constraints no cold food chains/transport is available as a result of which fresh produce endured post-harvest losses. There is a need to use production technologies supplemented with postharvest techniques to mitigate postharvest losses. **Directions for Future Research:** Many new technologically viable preservation techniques like modified atmosphere packaging and controlled atmosphere storage should come into existence due to increased health consciousness, increased purchasing power and an increase in percentage of postharvest losses (25-80% fresh produce) which could be applied with such economic constraints.

## INTRODUCTION

Agriculture, economy and trade are interrelated indicators of the socioeconomic status of a country. Agriculture is the largest sector of Pakistan's economy contributing to 21.4% GDP, 40% employment and 60% exports. Geographical area of Pakistan is 79.61 million hectares while under-cultivation is 22.04 million hectares. Our production technologies are more advanced than our preservation techniques so we need some advanced post-harvest methods to maximize the benefits. Fruits and vegetables are contributing 11% to the total value addition in the agriculture sector. In 2015, total area for the cultivation of fruits and vegetables was 588 thousand hectares, and production was 7612.4 thousand tonnes.

The fruits and vegetable market of Pakistan facing challenges due to poor supply chain infrastructure, due to which fruits and vegetables are wasted every year in substantial quantity. Fruits and vegetables are highly perishable commodities due to high moisture content and having limited shelf life. Temperature controlled environment is needed for their survival and Pakistan is lacking in cold storage facilities as we are facing an energy crisis. Post-harvest losses are between 35% and 40% and reducing these losses can not only improve farmer incomes, but could also encourage more consumption of highly nutritious fruits and vegetables in a region where per capita consumption is only half of the recommended level (Agricultural statistics of Pakistan, 2015-2016). Fruits and vegetables are rich sources of micronutrients, having great nutritional value and so are essential components of the human diet. In developing countries consumption of fruits and vegetables is 100g/person as compared to developed countries where it is about 220g/person. This situation is alarming because we are producing up to the mark but facing post-harvest losses due to some pre and post-harvest factors that can be controlled with proper management. Fruits and vegetable bear high post-harvest losses during transport and storage as they are living commodities and physiological functions like respiration takes place in them even after harvest. This leads to complete deterioration which render them unfit for consumption. This deteriorative action takes place at higher rates in the presence of humidity and high temperature (Idah et al., 2007). Generally it can be stated that overall quality and shelf life is reduced due to a number of factors (Rojas-Grau et al., 2008). Some physiological disorders take place, including moisture loss and energy deprivation, which bring detrimental changes in fruit quality. Inadequacy of preservation techniques results in impaired quality, and to cover these loopholes numerous innovative techniques are evolving to meet the demand of nutritious food, to maintain natural appearance and to extend shelf life of green groceries (Heyder et al., 2012).

The principal grown vegetables in Pakistan are potatoes and onions. The water for irrigation of vegetables came from snow covered mountains of north range. There are four seasons and such diversity in climate ensures abundant production of vegetables throughout year. Middle East, Malaysia, Singapore, Europe and Indonesia are main importers of vegetables from Pakistan. A diversified range of vegetables are grown in Pakistan having 63 total species and area elaborated in Table 1 (Athar & Bokhari, 2006). The most widely consumed vegetables are legumes, brassicas and cucurbits. All the vegetables are grown in peri urban centers like Multan, Lahore, Karachi, Hyderabad and Peshawar. Most of the vegetables are consumed fresh and very low percentage is processed. Vegetables have significance value due to large array of nutrients like antioxidants, lycopene and beta carotene.

**Table 1.** Range of vegetables are grown in Pakistan†

| Family | Species |
|---|---|
| Fabaceae (Leguminosae) | 15 |
| Cucurbitaceae | 11 |
| Brassicaceae | 7 |
| Solanaceae | 5 |
| Apiaceae | 4 |
| Chenopodiaceae | 3 |
| Amaranthaceae | 2 |
| Amaryllidaceae | 2 |
| Araceae | 2 |
| Asclepiadaceae | 2 |
| Lamiaceae | 2 |

† (Athar & Bokhari, 2006)

Pakistan has hot climate for most part of the year so that post-harvest preservation of vegetables is constrained by postharvest losses which affects farmers and agri businesses. Post-harvest losses are also due to perishable nature of vegetables and microbial decay. Lack of proper refrigerated storage and cold chains also plays its part in losses (Athar & Bokhari, 2006).

Growers and consumers of fresh produce bear economic and nutritional losses due to improper handling techniques which result in low market value and quality loss. Inadequate post-harvest management leads towards post-harvest losses that are about 25-40% in the case of fresh produce (Kader, 2004). Microbial decay and physical damage are common causes of post-harvest losses in fruits and vegetables. These losses can be minimized by adopting certain post-harvest preservation methods like edible coating, temperature control during storage and treatment with fungicides. In developing countries, post-harvest diseases destroy more than 30% yield of perishable commodities (Meena & Yadav, 2001). According to a recent study in developing countries post-harvest losses of fresh produce are up to 24-40% as compared to developed nations where these are 2-20% (Maiti et al., 2018). Post-harvest losses particularly in fruits and vegetables are 50% which occur at different stages from harvesting to consumption. At harvesting these losses are up to 20%, followed by 8% at handling, 10% at processing and packaging, 10% at distribution and 5% at consumption or household level (Elik et al., 2019). Usually losses occur due to improper post-harvest procedures including handling, transportation, storage and marketing, which results in deterioration and microbial contamination due to continuous modulation in physiological state of fruits and vegetables and biochemical reactions. During transportation of fruits and vegetables pathogens especially fungal attacks are very common that contribute to postharvest losses and tomatoes particularly are prone to fungal attack due to higher moisture contents and soft texture (Lee & Kader, 2000).

Advancements in production technologies are fast which results in an increased production of agricultural commodities but due to insufficient development and adoption of post-harvest technologies these crops bear huge post-harvest losses. About 50% of the third world population is deprived of adequate food supplies despite the fact that production is up to the mark due to adoption of new production technologies (Maiti et al., 2018). The main reason is postharvest losses that occur during transportation of fresh produce from farm to fork. Many pre harvest factors like poor production and harvesting techniques can contribute to it. Some other contributing factors are production of tomato varieties with low shelf life, infestation of produce with microbes, insects and pests, inefficient use of nutrients, harvesting with improper tools and use of techniques at less suitable times. Postharvest factors include incomplete removal of field heat, increasing moisture content during storage that facilitate infestation, packing produce without prerequisites like sorting and grading, lack of proper transportation facilities and market distribution to distant places. Economic losses, low foreign exchange and low return to growers are drawbacks of postharvest losses. These losses also vary according to nature of the crop. Postharvest losses of tomato, bananas, sweet potatoes and citrus fruits, vary from 50-70% (Etana et al., 2019). Worldwide values of postharvest losses range between 28-42%. In developing countries these losses are 50%, so it means that half of produced food is wasted before reaching consumers. This situation is alarming. Energy crises, lack of transportation facilities, complex marketing systems, and mechanical damage due to long distant transportation and technologies can lead towards higher percentages of losses (Munhuewyi, 2012).

Fresh commodities face many minor steps from farm to fork so postharvest handling needs special attention from harvesting till consumption and this step is crucial usually neglected. Identification, treatment and control of particular pathogens require technical knowledge. Environmental and climatic changes have an impact on mankind as well as on agricultural commodities. For example, temperature, ozone and carbon dioxide are influencing quality and production of fruits and vegetable crops worldwide.

Post-harvest losses in quality and quantity are also related to immaturity at harvest and, physical damage. The shelf life of tomatoes depends on the rate at which nutrients and moisture contents are reserved or lost and the rate of respiration. When tomato becomes depleted in food reserves and water loss occurs it begins to decay. Respiration rate, water loss and ethylene production can be controlled by keeping tomatoes at the appropriate temperature (10 ℃) (Fagundes et al., 2015). Wilting and shriveling occur due to water loss that renders tomatoes unusable for final consumer and results in post-harvest losses. To control these losses new techniques should be established and efficiency of already existing techniques should be reevaluated so that practical implementation should come into practice.

**Major reasons of post-harvest losses and biochemical changes during changes during post-harvest storage of fresh produce**

Fruits and vegetables are living matters having certain life evolving activities like respiration, transpiration, ripening and metabolic changes that are undesired sometimes. By controlling these metabolic changes, anything can be preserved to a specific period of time. Highly perishable commodities include most fruits and vegetables. According to FAO (2000), 50% of the third world population is deprived of adequate food supplies despite the fact that production is up to the mark. The main reason is postharvest losses that occur during transportation of fresh produce from farm to fork. One should not ignore pre harvest factors contributing to postharvest losses, like poor pre harvest measures and lack of advanced production and harvesting techniques. Some other contributing factors are production of tomato varieties with low shelf life, infestation of produce with microbes, insects and pests, inefficient use of nutrients, harvesting with improper tools and use of techniques at less suitable times. Postharvest factors include incomplete removal of field heat, increasing moisture content during storage that facilitate infestation, packing produce without prerequisites like sorting and grading, lack of proper transportation facilities and market distribution to distant places. Economic loss, low foreign exchange and low return to growers are drawbacks of postharvest losses. Developing countries are living on the edge and the percentage of losses is highest in third world countries. These losses also vary according to nature of the crop. Postharvest losses of soft textured commodities, for example tomato, bananas, sweet potatoes and citrus fruits, vary from 50-70%. Worldwide values of postharvest losses range between 28-42%. In developing countries these losses are 50%, so it means that half of produced food is wasted before reaching consumers. This situation is alarming. Energy crises, lack of transportation facilities, complex marketing systems, and mechanical damage due to long distant transportation and technologies can lead towards higher percentages of losses (FAO, 2000).

According to international agencies monitoring food security and world food resources the only option for meeting the needs of growing populations is to minimize postharvest losses. Fresh commodities face many minor steps from farm to fork so postharvest handling needs special attention from harvesting till consumption and this step is usually neglected. Handling of horticultural commodities is very crucial and technical knowledge counts a lot, for example identification, treatment and control of particular pathogens. Some other pre harvest factors that may contribute to disease are excessive nitrogen fertilization and overcrowded plants and postharvest practices; include spraying of water on vegetables. By adopting certain techniques, we can reduce losses up to 50% but complete elimination of postharvest losses is not possible. Production technologies supplemented with postharvest techniques are future of food security (Fatima et al., 2009).

In developing countries post-harvest losses mostly occur at picking, transportation and storage stage while in developed countries losses occur at consumer stage. To minimize post-harvest losses management and coordination of post-harvest stages of fresh produce plays an important role. The most common reasons of postharvest losses are mechanical damage due to vibration and impact, weight loss due to transpiration, use of improper containers and mode of transportation, improper harvesting techniques, harvesting at inappropriate maturity stage and early or late harvesting (Azabagaoglu, 2018). Harvesting of fresh produce is crucial stage and losses increase if a farmer does not have proper knowledge about maturity stages and proper picking time (Kasso & Bekele, 2018). Lack of storage facilities at harvesting sites lead to bruising and mechanical damage resulting in losses. Mother Nature also plays its role in post-harvest losses for example bad or uncertain weather conditions. Some soft textured fruits need extra care for example cherries require pre cooling and if not cooled 4-12% losses occur at this stage (Ozcan, 2018). Significance of proper storage cannot be denied in preventing losses and storage facilities required from production to consumption at several stages. Insufficient cooling and refrigeration facilities resulted in losses of perishable commodities up to 23% (IIR, 2009). There are many differences in storage practices and facilities among developed and developing countries as developed countries ensure to maintain storage temperature of fresh commodities throughout supply chain. Refrigerated or control atmosphere vehicles during transportation is a standard procedure in developed countries but in developing countries a lack of proper transportation infrastructure results in post-harvest losses. Loading and unloading by an aware/educated worker can further minimize losses (Azabagaoglu, 2018). By adopting suitable packaging losses can be prevented through avoiding moisture loss and minimizing transpiration and gaseous exchange. Fresh markets showcase unpackaged fresh produce which can make shelf life of fresh produce shorter. Poor quality packaging material causes more damage than benefits so selection of packing material should be of high quality and according to the nature of fresh produce (Kiaya, 2014). The practices being used in Africa and south Asia is to pack 46% of horticultural crops in sacks or large clothes bundles, 31% are packed in open baskets and 8% are sold as it is (Kitinoja & AlHassan, 2010). Considerable amount of losses occur at consumer stage of supply chain. Almost 50% of perishable horticultural commodities are being wasted by household. The reasons behind consumption waste are lack of planning, lack of proper storage facility at home and purchasing exceeding needs of family (Porat et al., 2018). The reasons of food wastage vary between developing and developed countries.

## Pathological incidence

A number of fungi cause postharvest losses, including *Alternaria alternata, Aspergillus niger, Aspergillus flavus, Fusarium, Fusarium solani, Penicillium, Geotrichum candidum, Cladosporium, Phytophathora capsici and Rhizopus stolonifer*. These were identified and isolated from fruits and vegetables as responsible for postharvest decay and diseases. Postharvest diseases are one of the main reasons for losses, and treatments to control these pathogenic and spoilage agents are expensive, which adds to high costs of fresh commodities passing through farm to final consumer (Fatima et al., 2009). Different fresh produces and their commonly occurring post-harvest diseases are illustrated it Table 2 (Snowden, 2008).

**Table 2.** Different fresh produces and their commonly occurring post-harvest diseases†

| Fruits/Vegetables | Post-harvest disease |
|---|---|
| Cucurbits family | Bacterial rot, Charcoal rot, Fusarium rot, Grey mould rot, Soil rot, Rhizopus rot, Watery soft rot, Sour rot, Pink mould rot, Cottony leak Powdery mildew, downy mildew, cucumber mosaic virus |
| Solanaceous family | Alternaria, Bacterial soft rot, Anthracnose, Bacterial speck, Early and late blight, Ghost spot, Fulvia rot, Phorna rot, Pleospora rot, Ring rot, Watery soft rot, Phytophthora rot, Pink mould rot, |
| Brassicas family | Black rot, Bacterial rot, Alternaria spot, Downy mildew, Phoma rot, Ring spot, Virus, White blister, Light leaf spot |
| Plum | Brown rot |
| Citrus | Green mold, Sour rot, Anthracnose, Aspergillus Black mold rot, Black pit, Bacterial canker, Cottony rot, Black spot, Scab |
| Bananas | Cigar end rot, Crown mould, Finger stalk rot, Cigatoka |
| Mangoes | Bacterial black spot, Black mould rot, Stem end rot |
| Chilies | Phytophthora root rot |
| Apple | Blue mold, Bitter rot, Mouldy core, Mucor rot, Scab, Side rot |
| Grapes | Grey mold, Rhizopus |
| Onion | Purple blotch, white rot, white tip, Downy mildew, Thrips, Rust, Smut, Bacterial rot, Black mould rot, Smudge |
| Tomato | Grey mold, Alternaria |
| Peas | Powdery mildew, Root rot, Leaf miner, Pod borer |
| Cabbage | Head cracking |
| Okra | Pod borer, Yellow vein mosaic virus, Jassids |
| Carrots | Cavity spot, Licorice rot, black rot, violet root rot, sclerotium rot, crater rot, rhizopus rot |
| Brinjal | Shoot and Fruit borer |
| Tinda gourd | Powdery mildew |

† (Snowden, 2008)

**Table 3.** Post-harvest losses occur at different levels of supply chain and due to different reasons†

| Supply chain stage | Post-harvest losses (%) | Corrupting factors for losses | Percentage of losses |
|---|---|---|---|
| Harvesting | 20 | Physical factors | 29 |
| Handling and storage | 3 | Physiological factors | 4 |
| Processing and packaging | 1 | Pathological | 9 |
| Distribution and retail marketing | 12 | | |
| Consumer stages | 28 | | |

† (Kiaya, 2014)

Pathogenic agents are not only responsible for deterioration of fruits and vegetables but they are detrimental to human health as well and can cause serious ailments, so they should be properly controlled or managed by adopting proper pre and post-harvest technologies. Mycotoxins are produced which make the fruits unfit for consumption, especially due to attack of pathogenic fungi which finds suitable conditions like lower pH, high moisture and the presence of suitable nutrients. Tomato comes under the category of highly perishable commodities, and its storage life is very low as it is prone to fungal attack, especially by *Botrytis cinerea* and *Rhizopus* species (Mari et al., 2008). The reason for easy fungal decay in tomato is due to its high moisture content, but after harvest water loss occurs, which leads to dehydration and wilting. Water loss can be regulated by vapor pressure differences caused by temperature and relative humidity. High postharvest respiration rates generate heat and water, and results in increased rate of water loss (Vargas et al., 2006). Vitamin C is most important nutritional quality factor in horticulture crops and its contents can be influenced by various pre and post-harvest factors. Solanaceae and Fabaceae families of vegetables are more prone to be attacked by *Phytophathora capsici* which also causes foliar blight, fruit rot and damping off on melon, pumpkins squashes, peppers and watermelons. Infestation occurs in the field during the growing season and results in stem lesions; seedling blight and vine rot during heavy rain fall periods due to high humidity which provides suitable environment for growth of these agents.

**Temperature management**

Management of temperature is very important in this context as vitamin C is heat labile and can be lost if storage is for a long time. To retain this valuable vitamin, bruising, mechanical injuries and excessive trimmings should be avoided. By controlling oxygen and carbon dioxide levels in storage, loss of vitamin can be reduced. Vitamin C losses continue through postharvest handling, processing, cooking, and storage and intensive research are needed to investigate the factors and to mitigate the possible losses. Improper temperature, inadequate initial quality control and delay between harvest and consumption and by paying special attention to these points losses can be minimized (Lee & Kader, 2000). Some other pre harvest factors that may contribute to disease are excessive nitrogen fertilization and overcrowded plants and postharvest practices; include spraying of water on vegetables. By adopting certain techniques, we can reduce losses up to 50% but complete elimination of postharvest losses is not possible. Production technologies supplemented with postharvest techniques are future of food security (Fatima et al., 2009).

Post-harvest losses occur at different levels of supply chain and due to different reasons as described in Table 3 (Kiaya, 2014).

Some factors that contribute towards degradation of chlorophyll during post-harvest storage are oxidation, chlorophyllases and pH changes. During different ripening and developmental stages, chlorophyll is converted into stable compounds called carotenoids. Protopectin is another compound that is converted into simple compounds during the maturation process that induces softening process and usually occurs when fruit is over ripe. Pectic substances degradation is directly proportional to softening of fruit. Ascorbic acid is converted into dehydroascorbic acid due to an oxidation process that continues after harvesting and with temperature changes during storage (Ahmad, 1982).

One of the reasons for softening of fruits during storage is catabolism of polymeric carbohydrates such as pectin and hemicellulose due to polygalacturonidases and esterases. Modification of cell wall polysaccharide and flesh firmness during post-harvest ripening of *Carica papaya* was evaluated. Cell wall material including pectin and hemicellulose fractions were isolated from pericarp during different ripening stages to observe solubility and depolymerization. A number of events occurred during ripening including, loss of galactose and release of rhamnose, but hemicellulosic fractions were not depolymerized at all. Water-extracted pectins were continuously depolymerized during the ripening process. Rhamnogalacturonan structure lost its monomeric acidic units during ripening. Softening was due to loss of connection between polysaccharides and microfibrils. Methyl esterification of water soluble pectins was increased, and decreased for middle lamella and primary cell wall pectins. So in this study, variations in firmness during the post-harvest ripening process of papaya were depicted as involving variations in cell wall polysaccharides and activities of different enzymes (Manrique & Lajolo, 2004).

Post-harvest fruit senescence was studied by Huang et al. (2005) especially the roles of water loss and calcium in litchi fruit (*Litchi chinensis* Sonn.). After detachment from the tree fruit membrane breakdown and desiccation were accelerated. Membrane breakdown in the inner part of pericarp (mesocarp) was evident just two days after harvest, and in sclerenchyma exocarp cells it was evident after 5 days. X-ray microanalysis showed deposition of calcium in epidermis cells. This concentration of calcium was the reason for fruit deterioration and membrane leakage.

Singh and Reddy (2006) determined changes in orange peel during a storage period of 17 days under refrigerated and ambient temperature to manage the other post-harvest stages before handling. Firmness, tensile strength of peel, puncture force and cutting energy decreased during storage due to the actions of pectin-degrading enzymes and softening that occurs as ripening proceeds. A comparison of different microscopic images of ripening kiwifruit was done at different softening stages with electron and light microscopes. Scanning electron microscopy (SEM) and Transmission electron microscopy (TEM) were used. Cell size and packing were different for three layers of tissue including the pericarp, inner pericarp and core. Volumes of intercellular air spaces increased with fruit softening. Outer pericarp showed immediate swelling of cell walls compared to the core, and plasmodesmatal tissues were not stained properly in ripe kiwi fruits. Ripe fruits contained broken middle lamella, and prior to ripening cell walls of fruits underwent ultra-structural changes during ripening. However, different fruits differed in extent of cell wall swelling, sustainability loss and time for structural changes (Hallett et al., 1992). Abovementioned studies shows that many physicochemical, compositional, Textural and microstructural changes occur during post-harvest life which ultimately results in post-harvest losses.

In another experiment related to ripening, pepino (*Solanum muricatum* Aiton) fruits were taken at three different ripening stages and stored at different temperatures ranging from 0-20 ℃ for 4 weeks. Ethylene production, respiration rate and pattern were temperature-dependent, as there were low respiration rates at 20℃. When fruits were exposed to 10 ppm ethylene, an increase in respiration rate up to 30% was observed. Ripening fruits were successfully stored at 5 ℃ for 4 weeks without causing chilling injury or any decay, but less ripened fruits underwent decay within 2 weeks of storage (Ahumada & Cantwell, 1996).

Post-harvest losses are also commodity and region dependent, and include losses that occur during harvest due to lack of harvesting equipment, and proper shipping and transportation, even after reaching to consumer. To control these losses, an understanding of the etiology and biology of post-harvest diseases and controlling strategies are crucial. Storage, shipment and marketing sometimes provide very suitable environments for a wide spread fungal pathogen like *Botrytis cineria*. Harvested crops undergo different biochemical changes leading towards senescence and become an easy target for this fungus. Etiological and epidemiological studies of plants are very important in developing control programs, for example pre harvest management by fungicidal sprays to reduce inoculum density. Use of chemicals, especially on post-harvest commodities, is regulated and restricted now, so there is a need to develop environmental-friendly and efficient methods for controlling Botrytis rot. There is a very strong relationship between pathogen infestation in the field and development of different microbial decays in storage. This relationship needs to be elucidated in certain fruits, including strawberry, kiwifruit, grapes, roses and tomatoes, having different approaches to tackle the situation. Some control measures involve prediction and modeling systems like physical and biological methods, cultural practices and early detection techniques (Droby & Litcher, 2007).

Temperature is a significant factor that can influence the photosynthesis processes of crops, and in this way has the ability to alter quality of produce by modifying synthesis of certain nutrients, such as sugars, organic acid and antioxidants. Textural properties such as firmness are also temperature dependent. On the other hand, some gases, like carbon dioxide, contribute to global warming. Prolonged exposure of commodities to carbon dioxide can result in tuber malformation and accumulation of sugar in potatoes, as well as protein and mineral decreases, which result in loss of sensory quality and nutrition. Another environmental factor is ozone in the atmosphere, which can affect post-harvest quality of fresh produce by inducing visible injury and physiological disorders. It can also alter the nutritional status of fruits and vegetables by reducing dry matter, sugar, citric acid and malic acid. When some fruits, like strawberries, were kept in ozone-enriched environments, having different concentrations (ppm) of ozone gas the post-harvest quality can be improved through inhibiting pathogenic microbes and fungi moreover, vitamin C tended to increase and emission of volatile esters was decreased significantly. Beta carotenes, lutein and lycopene contents were increased in tomatoes exposed to ozone (Moretti et al., 2010).

In a research study, post-harvest losses of tomatoes in the Peshawar valley of Pakistan were presented (Khan & Jan, 2007). Surveys were conducted to learn about farmer, s ideas of the nature and processing of tomatoes. The author was able to estimate post-harvest losses of tomatoes in that area during Kharif (crops cultivated in rainy season) 2006. Data collected from 68 tomato varieties showed that post-harvest losses are about 20%, and mainly occur during harvesting, handling and transportation of tomatoes to markets. To curtail these losses extension and information services should be offered to educate and train farmers about the latest packaging techniques, processing and advanced handling technologies. Estimating actual and real percentages of post-harvest losses is a challenge due to a lack of generally accepted methods, but it can be concluded that losses are occurring at high percentages. Tomato growers in the Peshawar area farm from 0.5 acres to 5 acres, with an average area of 1.37 Acres. Shimla and Grifton varieties were very commonly grown in that area due to special traits including flesh, color and shape. The reason for the 20% loss of tomato crop is improper handling and transportation. Usually the tomatoes were harvested in the morning and then transported to distant markets in wooden crates. Farmers should be educated about physiological and biochemical reactions that occur after harvest and during storage so that they may be able to tackle post-harvest-related issues. It can be concluded that standardization of preharvest and post-harvest protocols are required to curtail these losses and to earn maximum foreign exchange. Quality of tomatoes mainly depends on handling procedures during harvesting, grading, packing and transportation.

A study was conducted that consisted of a survey to illustrate distribution of the tomato crop in Lahore, Punjab, Pakistan. The Survey showed the damage of the tomato crop was due to packing material (25%) and transportation system (10%). Total post-harvest losses were approximately 30%, with exceptions when whole lots were lost. Some factors were transportation time lag and high humidity due to packing material (wooden crates with paper) which would ultimately provide favorable environments for mycoflora to grow. Spoilage fungi, especially in tomato, include *Aspergillus nige*, *Rhizopus stolonifer*, *Fusarium* *oxysporum* and *Botrytic cineria.* Minimum losses were observed during storage, grading and distribution of tomatoes. Management and post-harvest techniques can be used to reduce these losses, like minimizing the ethylene concentration in the surrounding environment of tomatoes, grading to separate bruised and injured tomatoes to avoid proliferation of microbes and further damage, and temperature and relative humidity control. More detailed and investigative surveys are required to control or manage post-harvest losses in tomatoes or to build strategies that can help in increasing foreign exchange (Saeed & Khan, 2010).

The ripening process of tomato fruit is a result of a series of coordinated biochemical reactions which impart some quality and sensory attributes to ripened tomatoes. During storage of tomato changes in neutral sugar, protein content and uronic acid take place. During the ripening process galactose, arabinose and galacturonic acid declined (Gross & Wallner, 1979). During ripening of tomatoes softening occurs due to degradation of pectin substances through enzymatic degradation. Insoluble pectin converts into soluble pectin through polygalacturonase enzyme action. Cellulose which is also a structural component in tomatoes also decreases during ripening, leading towards softening due to a reduced number of cellulose microfibrils and increase in micellar size of cellulose with time, especially in peaches and apples. There is a need to identify enzymes that are involved in hydrolysis of cellulose and induces softening in fruits and vegetables. These cellulolytic enzymes are produced by microbes and only tomatoes and dates are enriched with these enzymes. Cellulases can be classified as exocellulase and cellobiase acting on carboxymethyl cellulose (CMC) and cellulodextrins. In tomatoes cellulase and cellobiase are involved in cellulolytic activity. Cellulase degrades CMC in tomatoes but will not act on native cellulose. Tissue softening and disintegration that leads to complete decay and post-harvest losses is due to action of different cellulolytic and pectin degrading enzymes and can be controlled by decreasing their activity.

During ripening, pectin, which is a very important compound in middle lamella, is solubilized due to the action of different enzymes, especially polygalacturonase (PG). This enzyme is involved in cell wall breakdown, loss of tissue integrity and fruit softening. This pectin degrading enzyme usually accumulates in cell wall of ripe tomato fruits. The effect of reduced PG activity was determined in processing and fresh tomato products. Analysis showed that serum viscosity was significantly increased in processed tomato paste, and in fresh tomatoes, softening was decreased during post-harvest storage. Self-induced reduced PG activity also showed some antimicrobial potential in ripened tomatoes, especially against some fungal strains that usually attack tomatoes during ripening, including *Geotrichum candidum* and *Rhizopus stolonifer*. Through manipulation of PG levels, phenotypic changes and quality characteristics of tomatoes can be controlled by inducing modulations in pectic substances (Kramer et al., 1992).

Post-harvest management of tomatoes and other fruits and vegetables emphasize limiting biological variations through sorting and grading and controlling batch behavior at different stages of the post-harvest chain. Hertog et al. (2004) determined the post-harvest behavior of tomatoes under the impact of different biological variations. Color changes of tomato fruit were determined at different times and temperatures to develop a kinetic model to explain biological variations during post-harvest storage.

Musse et al. (2009) monitored the post-harvest ripening of tomatoes using quantitative magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) relaxometry during 3 weeks after harvest. Estimation of such parameters was done using different image types, including spin echo images and echo time gradient. Quantitative MRI images were used to determine variation in the longitudinal and transverse relaxation times. NMR provides information about sub cellular compartments, water distribution, water content, weight loss and concentration of neutral sugars and acids. Macroscopic as well as microscopic structural changes were observed, including shrinkage of air spaces and development of bubbles in the outer pericarp during ripening. Rejection and acceptance of tomatoes can be made by comparing NMR characteristics of individual tomatoes with predetermined values.

Carotenoids are metabolized during tomato ripening, and it is a temperature dependent process. This was revealed by an experiment in which pericarp tissue sections of tomatoes were stored at different temperatures and then incubated with $C^{14}$ mevalonic acid, a precursor of carotenoids. It was observed that radioactivity of lycopene a carotenoid found in tomato fruit, was low at high temperature, while high for beta-carotene. Carotenoid biosynthesis pathway includes conversion of phytoene into lycopene and finally into beta carotene. Accumulation of lycopene can be inhibited by inducing high temperatures as lycopene is immediately converted into beta-carotene (Hamauzu et al., 1998).

Lycopene contents of tomatoes are directly related to its ripening stage and Raman chemical imaging was used to map complex constituents in food matrices (Qin et al., 2011). Internal lycopene distribution was analyzed and visualized through this imaging system during post-harvest ripening of tomatoes. Tomato slices were kept under an imaging machine to get ramanimages, and these images were subjected to a hyperspectral image classification method to identify lycopene in tomato cross sections. Results indicate that quantification of lycopene is a very good maturity index for tomatoes to measure ripeness of tomatoes. Tomato lycopene contents increases as ripening proceeds and were highest at the red stage. During post-harvest storage antioxidant contents of tomatoes depends on environmental conditions and accumulation kinetics of antioxidants varies a lot. Lycopene tends to accumulate in early stages of ripening and is related to color changes (Giovanelli et al., 1999).

Antioxidant activity of vine ripe tomatoes was monitored at different ripening stages and then examined relationships with total phenolic contents, ascorbic acid, lycopene and β-carotenes. Total phenolic contents were increased during different ripening stages but ascorbic acid remained constant. Lycopene tended to accumulate throughout ripening process while beta-carotene increased until the breaker and pink stages. Antioxidant activity was correlated with lycopene and ascorbic acid contents (Cano et al., 2003)

Color development in tomatoes depends on storage conditions as well as maturity stages (Tijskens & Evelo, 1994). Further, Javanmardi and Kubota (2006) studied how different traits like lycopene, total soluble solids, antioxidant activity, and weight loss vary during post-harvest storage of tomatoes. During post-harvest storage biological and therapeutic activities of some inherent compounds changes due to environmental changes and as a result of phytochemical reactions. Cluster tomatoes were stored for two weeks at refrigeration temperature and during this time variation in lycopene, antioxidants and total soluble solids were measured. Low temperature storage results in less weight loss, and lycopene and TSS enhancement as compared to tomatoes kept at room temperature.

Chilling stress can alter biochemical pathways involved in production of antioxidant compounds. Environmental conditions in which fresh produce is stored should be appropriate to keep the biochemical moieties intact. Temperature fluctuations during post-harvest storage of tomatoes can influence concentrations of lycopene, phenolic compounds and activity of antioxidant compounds (Javanmardi & Kubota, 2006).

Vitamin C content in tomatoes is influenced by many post-harvest and preharvest factors. Ascorbic acid and dehydroascorbic acid have many biological activities in human body, thus are important nutritional quality factors. Pre harvest climatic conditions and cultural practices, genotypic differences, maturity and harvesting methods, and post-harvest handling procedures can influence ascorbic acid content. Intensity of light can boost the production of vitamin C but using high doses of nitrogen fertilizers can decrease the vitamin C content. Post-harvest temperature management is important in maintaining vitamin C content as losses are accelerated at higher temperatures and long storage (Lee & Kader, 2000). Mechanical injuries and bruising can also lower the retention of vitamin C. Loss of vitamin C can be controlled by reducing oxygen and increasing carbon dioxide up to 10%. A significant amount of ascorbic acid is lost during processing and cooking of tomatoes. Changes in major antioxidant quantity and efficacy of tomatoes during post-harvest storage were evaluated by Toor and Savage (2006). Tomatoes were stored at different temperatures for a period of 10 days and then phenols and ascorbic acid content of tomatoes were measured. These two parameters slightly increased during storage up to two-fold. Harvesting techniques and storage conditions also have impact on final quality of tomatoes (Moneruzzaman et al., 2009). Tomatoes at different stages of ripening were kept under different storage conditions. Different harvesting stages and storage conditions can induce variations in quality characteristics of tomatoes.

One main reason for post-harvest losses is oxidative stress, which results in the generation of reactive oxygen species at high rates so the cellular redox homeostasis of the plant is disturbed, such that the plant does not have the capability to scavenge free radicals. Environmental stress usually results in production of reactive oxygen species. Some symptoms of oxidative stress in fruits are inhibition of chloroplast development, core browning, superficial scald, disruption in membrane integrity, inactivation of protein due to action of proteases and bleaching of pigmentation. Many factors influence post-harvest oxidative stress, including harvesting technique, storage condition, temperature and atmosphere. A phytohormone ethylene is considered to be involved in rapid ripening process and sometimes the oxidative reactions like lipid peroxidation continues to propagate due to ethylene contact. Ethylene activity and synthesis can be stimulated through lipoxygenase activity and reactive oxygen species that can accelerate ripening and senescence (Hodges et al., 2004).

Another major reason of tomato losses after harvest is microbiological decay, and among microbiological decays fungal decay is more significant than bacterial decay. *Botrytis cineria* is a very common fungal species that causes the post-harvest disease called grey mold. This causes economic loss and also makes it impossible to transport fresh produce to long distance areas. It enters through bruises and wounds that result from mechanical injury or directly penetrates into tomatoes. It has the capacity to grow even at low temperatures, and propagates quickly, so needs to be controlled. Fungicides can be used, but only in limited amounts and types as it can create a hurdle in import and export of tomatoes.

The microbiological quality of tomatoes also depends on storage conditions specially temperature. *Salmonella Montivideo* tends to cause salmonellosis in tomatoes and tomato based products and several cases had been reported in past. Normal defense mechanism of tomatoes can stop infiltration of bacteria but tomatoes are usually harvested at green stage and allowed to ripen in boxes where temperature ranges are 15-25 ℃ that can promote proliferation of this bacterial strain. Other ripening factors like low acidity, increasing sugar content and lycopene and loss of plant cell wall integrity can contribute towards its growth. In post-harvest tomatoes this infiltration is easy comparatively due to weak defensive mechanism. Keeping tomatoes at lower temperature after harvest can retard growth of salmonella but it can delay ripening and can cause chill injury (Shi et al., 2007).

## CONCLUSION

Food security is a serious problem of present era and to ensure food security issue we should focus on production technologies supplemented with adequate preservation techniques. According to United Nations World Food program, 60% population of Pakistan is facing food insecurity. Post-harvest losses of fresh produce specially fruits and vegetables is a common and prevalent problem across the world and should be addressed on priority. Production technologies supplemented with post-harvest techniques is need of time. Simple and technologically viable preservation techniques should be developed like strengthening containers to avoid mechanical damage during handling and transport, natural cooling techniques for temperature management, disinfestation techniques, low energy cooling practices and educating farmers and handlers. Post-harvest losses in Pakistan can be minimized by effective communication among different departments like research, agriculture, food technology, economist and extension facilities. The first step towards improvement is overcoming all socioeconomic constraints.

**Conflict of interest**
The author has no conflict of interest to report.

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