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## POSTHARVEST MANAGEMENT OF FRUITS AND VEGETABLES – A REVIEW

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### ABSTRACT

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Fruits and vegetables are perishable crops that suffer great losses both in quantity and quality after harvest. These produce require integrated approach to stop their spoilage and overcome the present day challenges. Lack of postharvest awareness and absence of sufficient and functioning equipment in the postharvest chain result in serious postharvest losses in developing countries. A clear and comprehensive understanding of postharvest deteriorative factors is necessary to overcome these challenges. Pre and postharvest management such as good cultural practices, use of improved varieties, good handling practices pre and postharvest, temperature and relative humidity management, storage atmosphere management, use of permitted chemicals, design of appropriate packaging materials and storage structures are some of the control measures use in reducing postharvest losses.

### 1.0 INTRODUCTION

Fruits and vegetables are living parts of plants containing 65 to 95 per cent of water. They continue their life metabolisms after harvest and thus change their characteristics depending on product handling, storage and treatment (Faye, 2007). They are highly valued in human diet, rich in vitamins and minerals (Hassan, 2010), antioxidants, bioflavonoids, flavor compounds and dietary fibre (Choudhury, 2006). Postharvest technologies constitute an inter-disciplinary science and techniques applied to agricultural commodities after harvest for the purpose of preservation, conservation, quality

control/enhancement, processing, packaging, storage, distribution, marketing, and utilization to meet the food and nutritional requirements of consumers in relation to their needs. Postharvest technology stimulates agricultural production, prevents post-harvest losses, improves nutrition and adds value to agricultural products thereby opening new marketing opportunities and generating new jobs while stimulating growth of other related economic sectors (Kader, 2002a). Produce losses, in quantity and quality, can occur at any step during the postharvest chain, with important economic impact (Marta *et. al.*, 2014).

The most important losses in agricultural production which involve the greatest costs on the farm economy occur postharvest. It is estimated that worldwide between 10 and 40% losses of agricultural produce occur postharvest. Losses are more severe in developing than developed nations (Enyiukwu *et. al.*, 2014). The factors contributing to these losses includes; the initial quality of the crop, mechanical injury, temperature, humidity, types of handling given to the crop and storage atmosphere. It was also observed that a substantial amount of postharvest losses have their origin in the pre-harvest stage for example genetic factors, infections, pest-infestation, environmental factors and cultural practices during production stage (Atanda *et. al.*, 2011). Damage may occur at any point from growing through to the final point of sale; it may arise through external or internal forces (Alistair, 2006). Reduction of these losses, particularly if they can be avoided economically, would be of great significance for producers and consumers alike (Faye, 2007). The three main objectives of applying postharvest technology to harvested fruits and vegetables are to maintain quality (appearance, texture, flavor and nutritive value), protect food safety, and to reduce losses between harvest and consumption (Lisa and Kader, 2003).

Safety and perishability are the two most important concerns in all fruits and vegetables. Safety is determined principally by the presence of a pathogen or toxic chemical in the fruit or vegetable. Perishability is caused by microbial degradation, enzymatic activities and/or chemical reactions, which may result in undesirable changes in sensory, physical and nutritional properties of the product. Fruits and vegetables vary in their perishability, depending on their composition and how they are processed,

packaged and stored (Ooraikul, 2003). Consumers increasingly require food products that preserve their nutritional value, retain a natural and fresh colour, flavour and texture, and contain fewer additives such as preservatives. These requirements pose new challenges for fruit and vegetable producers and processors (Jongen, 2002).

## **2.0 Harvesting Fruits and Vegetables**

As long as they are not harvested, the quality of fruits and vegetables remains relatively stable. If they are not damage by disease or eaten by insects or other animals. However, the harvest cannot be postponed indefinitely (Ife and Bas, 2003). Proper timing, good methods of harvesting and devoid of mechanical injuries are determinants of fruits and vegetables quality (Alistair, 2006 and Atanda *et. al.*, 2011). Once harvested, any natural resistance to the action of spoiling micro-organisms is lost. Changes in enzymatic systems of the fruit also occur on harvest which may also accelerate the activity of spoilage organisms (FAO, 2005). Fruits and vegetables must be handled carefully if they are not to deteriorate before they reach consumers as fresh retail products or manufacturers for further processing (Jongen, 2002). To retain the desired qualities of horticultural crops they must be treated with the goal of stopping physiological aging, enzyme changes and prevention of microbial growth (Ife and Bas, 2003).

Some fruit and vegetables can be stored for a long time after they have been harvested, but others are more delicate and susceptible to spoilage and cannot be stored for long (Susan and Charlotte, 2008). Maturity at harvest is the most important determinant of storage-life and final fruit quality. Immature fruit are highly susceptible to shriveling and mechanical damage, and are of inferior flavor quality when ripe.

Overripe fruit are likely to become soft and mealy with insipid flavor soon after harvest. Fruit picked either prematurely or too late, are more susceptible to post-harvest physiological disorders than a fruit picked at the proper stage of maturity (Kader, and Rosa, 2004).

Insufficient knowledge, with respect to good handling practices is the major contributing factor to post harvest losses of fruits and vegetables (Azizah *et. al.*, 2009). Workers must be trained to harvest produce without causing damage. Injuries can occur at the time of harvest if care is not taken. These injuries can include finger bruises, inappropriate removal of plant parts, e.g. stems from the fruit, and impact bruising if produce is dropped into picking containers. When possible, highly perishable fruits and vegetables should be harvested during the morning when product temperatures are lowest. Harvesting early in the day can be especially important if refrigeration capacity is limited (Chris and Jacqueline, 2012). A matured ripe fruit should be picked gently by a mild twist and pulling.

Good sanitation management in all pre and postharvest operations will help in eliminating sources of infection and reducing levels of contamination. Disinfection during harvest and postharvest processes are vital components of a postharvest management plan. As food safety regulations become increasingly important to the sale and marketing of crops, the establishment of proper measures to ensure the elimination of food-borne pathogens is essential. In addition to mitigating potential food-borne illness, proper sanitation during postharvest handling can also minimize the occurrence of postharvest disease and decay (Chris and Jacqueline, 2012).

### **3.0 Effects of Preharvest Factors on Postharvest Quality**

The postharvest quality of fruits and vegetables are largely determined by preharvest factors such as production location, soil type, irrigation, rootstock, shading and nutrition. Preharvest factors are divided into primary and secondary. The primary factors include climate, nutrition and plant growth regulators, and the secondary factors include soil quality and management, rootstock, irrigation, pruning and crop load manipulation. Wang (1997) and Kader (2002b) reported that soil type, the rootstock used for fruit trees, mulching, irrigation, fertilization and other cultural practices influences the water and nutrients supply to the plant, which can affect the composition and quality attributes (appearance, texture, taste and aroma) of the harvested plant parts. Kader (2002b) also reported that climate conditions, especially temperature and light intensity have a strong effect on the nutritional quality of fruits and vegetables. Field management practices such as pest control, soil fertility and water management plays important roles in determining quality attributes such as size, colour, flavour, texture and nutritional value of vegetables (Wang, 1997)

Wang (1997) reported that mineral elements, especially N and Ca, have profound effect on firmness, ethylene production, respiration, storage life, ripening and decay of diverse fruits and vegetables. Development of disorders during postharvest ripening and storage of fruit depends on a range of preharvest factors. Fruiting position on the tree and fruit temperature history are two of the most important of these factors, example, in apples, position strongly influences fruit mineral contents, and consequently incidence of postharvest disorders such as bitter pit.

Specific disorders such as watercore in apples and chilling injury in avocado can also be related to fruit exposure to sunlight and high temperatures; disorders such as scald in apples may be related to frequency of low temperature exposure over the season (Ferguson *et al.*, 1999).

Stanley (1999) reported that a wide range of preharvest factors can modulate the appearance of the harvested product. These factors include: (1) biological factors (pathological, entomological, animal); (2) physiological factors (physiological disorders, nutritional imbalances, maturity); (3) environmental/cultural factors (e.g. climate, weather, soils, water relations, light intensity); (4) mechanical damage; (5) extraneous matter (growing medium, vegetable matter, chemical residues); and (6) genetic variation and aberrations.

#### **4.0 Climacteric versus Non-climacteric Fruit**

**Climacteric fruit** can be harvested when mature but before the onset of ripening. These fruits may undergo either natural or artificial ripening. The onset of ripening is accompanied by a rapid rise in respiration rate, generally referred to as the respiratory climacteric. After the climacteric, the respiration rate slows down as the fruit ripens and develops good eating quality. Examples of climacteric fruit include: apples, bananas, melons, papaya and tomatoes (Somjate, 2006).

**Non-climacteric fruit** ripen only while still attached to the parent plant. Their eating quality suffers if they are harvested before they are fully ripe because their sugar and acid contents do not increase further. Their respiration rate gradually declines during growth and after harvesting. Maturation and ripening are a gradual process. Examples of climacteric fruit

include: cherries, cucumbers, grapes, lemons and pineapples (Somjate, 2006).

#### **5.0 Principal Causes of Postharvest Losses and Poor Quality**

The most common causes of postharvest losses in developing countries are high field heat on crops before harvesting, pests and diseases attack (Ayandiji and Omidiji, 2011), rough handling, inadequate cooling and temperature maintenance, lack of sorting to eliminate defects before storage and the use of inadequate packaging materials (Lisa and Kader, 2003).

As soon as the fruits and vegetables are cut off from their natural nutrient supply, their quality begins to diminish. This is due to a natural process that starts as soon as the biological cycle is broken by harvesting. Once harvested, they are edible for only a limited time, which can vary from a few days to weeks. The product then begins to spoil or rot. Spoilage of fruits and vegetable can be cause by physical/environmental factors, physiological changes, insects and rodents, chemical and enzyme, mechanical damage and microorganisms (Ife and Bas, 2003).

#### **5.1 Spoilage by environmental factors**

Climatic factors, in particular temperature and light intensity greatly influence the nutritional quality of fruits and vegetables as does the location of production and the season. Rainfall and temperature affects water supply to the plant, which in turn affect the rate nutrients absorption (Kader and Rosa, 2004). High temperatures are very injurious to perishable products. In growing plants, transpiration is vital to maintaining optimal growth temperatures. Organs removed from the plant, however, lack the protective effects of transpiration, and direct sources of heat, for example full sunlight, can rapidly heat

tissues to above the thermal death point of their cells, leading to localized bleaching or necrosis (sunburn or sunscald) or general collapse (Kader, 2006).

If the humidity of the storage environment exceeds the equilibrium relative humidity (ERH) of the food, the food will gain moisture during storage, and vice versa (Alistair, 2006). Relative Humidity directly affects the storage quality of products as excessive water loss results in wilting, shriveling, flaccidness, soft texture and loss of nutritional value as well as saleable weight. For most fruits and vegetables the humidity should be kept high. While high RH approaching 100% can encourage growth of microorganisms and splitting of skin surfaces, it is usually more of a problem to maintain sufficiently high humidity than the opposite (Chris and Jacqueline, 2012).

### **5.2 Mechanical damage**

Fruits and vegetables should be handled carefully to avoid bruises, skinning, damage due to impact and compression injury, and friction damage (Chris and Jacqueline, 2012). Poor handling, unsuitable packaging and improper packing during transportation are the cause of bruising, cutting, breaking, impact wounding, and other forms of injury in fresh fruits and vegetables (Choudhury, 2006). Mechanical damage during harvest can become a serious problem, as injuries predispose produce to decay, increased water loss and increased respiratory and ethylene production rates leading to quick deterioration (Lisa and Kader, 2003).

It is necessary to consider both the stresses imposed during the transport and those encountered during loading and unloading (Alistair, 2006). Some products will generate ethylene, potentially damaging other products in the same load. So load compatibility is an important

consideration during transportation (George *et. al.*, 2009). Roads between the field, packinghouse and market should be graded and free from large ruts, bumps and holes. Field boxes must be well-secured during transport and, if stacked, not overfilled. Transport speeds must be suited to the quality and conditions of the roads, and truck and/or trailer suspensions kept in good repair. Reduced tire air pressure on transport vehicles will reduce the amount of motion transmitted to the produce (Lisa and Kader, 2003). In addition to impact damage that can occur by allowing fruits and vegetables to bounce around, friction damage can occur as a result of products moving against each other and against container walls (Chris and Jacqueline, 2012).

### **5.3 Chemical and enzyme spoilage**

Contamination by chemicals may be caused by either naturally occurring substances or by synthetic chemicals that may be added or are present during agricultural production or post-harvest treatment and further processing. In order to minimize risks of chemical contamination of fresh products, it is important to: (1) Make minimal and correct use of chemical additives (e.g. agrochemicals, processing and treatment agents, packing additives, pest control agents, antibiotics), (2) Prevent contamination during product handling and processing by identifying potential risks and implementing adequate proper practices and countermeasures (Faye, 2007).

Enzymes which are endogenous to plant tissues can be undesirable; they may cause postharvest senescence and spoilage of fruits and vegetables, oxidation of phenolic substances in plant tissues by phenolase (leading to browning), sugar-starch conversion in plant tissues by amylases, post-harvest demethylation

of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing) (FAO, 2005). Chemical and enzyme spoilage occurs especially when vegetables and fruits are damaged by falling or breaking. Such damage can release enzymes that trigger chemical reactions. The same processes can also be triggered by insects: the fruit becomes damaged, which causes enzymes to be released (Ife and Bas, 2003).

#### **5.4 Biological spoilage**

Biological hazards in fresh produce come from micro-organisms such as bacteria, fungi (yeasts and moulds), protozoans, viruses and helminthes (worms). In some cases, microbial contamination is indirectly introduced by pests, which may carry pathogens that can contaminate the food (Faye, 2007). Microorganisms readily attack fresh produce and spread rapidly, owing to the lack of natural defense mechanisms in the tissues of fresh produce, and the abundance of nutrients and moisture which supports their growth (Choudhury, 2006). All freshly harvested produce has naturally occurring bacteria, yeast and mold cells. These “contaminants” are associated with dust, insects, soil, rainfall, and sometimes humans (Chris and Jacqueline, 2012). Washing, cleaning and sanitizing procedures prior to packing reduce the number of potential pathogenic micro-organisms on fresh produce and thus prevent foodborne diseases (Faye, 2007). Several species of microorganisms participate in postharvest deterioration and rots of horticultural produce. These include species of *Aspergillus*, *Fusarium*, *Colletotrichum*, *Macrophomina*, *Penicillium* and *Rhizopus* amongst several others (Enyiukwu et. al., 2014). Both the organisms themselves and toxic products lead to deterioration of quality, as well as posing safety problems (Alistair, 2006).

Insects and rodents can cause a lot of damage. Not only by eating the products, but also by passing on micro-organisms through their hair and droppings. The affected parts of the plants are then especially susceptible to diseases (Ife and Bas, 2003).

#### **5.5 Physical hazards**

Physical hazards may be introduced as foreign material into fresh fruits and vegetables at numerous points in the production chain. Foreign material in fresh produce can result in serious injury and illness for the consumer. Most of these physical hazards are related to poor handling practices during harvesting, washing, sorting and packing of products. To ensure the food safety of fresh produce it is important to (1) Identify possible physical hazards along the production chain (agriculture and post-harvest processes), and (2) Implement proper practices and countermeasures that will create awareness and responsibility among workers (Faye, 2007). Proper quality of all processing water that contacts fresh produce during cleaning, grading, cooling and application of surface treatments is widely recognized as the principal key to ensure food safety (Kader, 2013).

#### **6.0 Effects of Ethylene on Fruits and Vegetables**

Ethylene is a gas that is produced by some fruit and vegetables when they ripen. Some fruits and vegetables are sensitive to the gas and will ripen if they are exposed to it. If ethylene-sensitive products are stored in the same place as ethylene producing ones, the sensitive ones will be spoilt during storage. High ethylene producers include ripe bananas, cantaloupe melons and apples. Ethylene sensitive products include lettuce, carrots, potatoes and cucumbers (Susan and Charlotte, 2008).

Responses of commodities to ethylene can be affected by species, variety, cultural practices, prior exposure to hormones, and levels of past and current stresses. There is no set standard for ethylene concentrations at which detrimental effects will occur and there are important differences in ethylene sensitivity among fruit and vegetable types. Climacteric fruit such as apples and pears have high ethylene production and high sensitivity, while other products (e.g. broccoli, cabbage, carrots and strawberries) can have low rates of ethylene production but are highly sensitive to ethylene. Most non-climacteric fruit, such as cherry, grape, berries and pepper, have low ethylene production and low sensitivity to ethylene (Chris and Jacqueline, 2012).

Detrimental effects of ethylene are often of more concern to growers and marketers. Exposure of ethylene to unripe climacteric fruit can cause earlier than desirable ripening, resulting in overly soft and mealy fruit. More commonly in the marketplace, ethylene exposure can result in undesirable yellowing of green vegetables such as cucumbers, parsley and broccoli, and many other negative effects. Exposure of vegetables and non-climacteric fruits also increases their respiration rates, meaning that the carbohydrate reserves are used more rapidly, as well as increasing water loss. Typically, exposure occurs from mixing ethylene producing and ethylene sensitive commodities in the same storage room (Chris and Jacqueline, 2012).

#### **7.0 Prevention of Postharvest Losses**

In general, minimizing rough handling, sorting to remove damaged and diseased produce and effective temperature management will help considerably toward maintaining a quality product and reducing storage losses. Storage life will

be enhanced if the temperature during the postharvest period is kept as close to the optimum as feasible for a given commodity (Lisa and Kader, 2003). Processing activities are of critical importance to expansion and diversification within the fruit and vegetable sector in that they increase market opportunities for fresh fruits and vegetables and add value while minimizing postharvest losses (Rosa, 2006). Spoilage can be control by arresting physiological aging, enzyme activities and microbial multiplication (Ife and Bas, 2003). The commonly used methods to prevent spoilage of fruits must include: (1) Care to prevent cutting or bruising of the fruit during picking or handling. (2) Refrigeration to minimise growth of micro-organisms and reduce enzyme activity. (3) Packaging or storage to control respiration rate and ripening. (4) Use of preservatives to kill micro-organisms on the fruit (FAO, 2005).

#### **7.1 Good quality raw material**

No matter how perfect postharvest operations are, good returns cannot be obtained from poor quality raw materials. The selection of suitable varieties is, therefore, essential. Linking production to postharvest operations is essential to optimizing results. Pre-harvest parameters such as selection of proper planting material, crop management, and disease and pest control must be geared toward producing high quality produce. Once the crop is ready for harvest, attention must be paid to the harvesting technique/procedure (Choudhury, 2006).

#### **7.2 Temperature and relative humidity management**

Temperature management is the most effective tool for maintaining quality and safety and for extending the postharvest life of fresh horticultural commodities. It begins with the rapid removal of field

heat by initial cooling and continues throughout the processing chain. Management of relative humidity along with temperature is essential in reducing water loss (Kader, 2013). The quality and storage life of fruits and vegetables may be seriously compromised within a few hours of harvest unless the crop has been cooled promptly to control deterioration (Liberty *et. al.*, 2013). Most perishable horticultural commodities last longest at temperatures near 0°C. At temperatures above the optimum the rate of deterioration increases 2- to 3-fold for every 10°C rise in the temperature. Temperature influences how other internal and external factors influence the commodity, and has a dramatic effect on the spore germination and growth of pathogens (Kader, 2006). The rate of biochemical reactions is related to temperature, such that lower storage temperatures lead to slower degradation of foods by biochemical spoilage, as well as reduced growth of bacteria and fungi (Alistair, 2006). Exposure to the sun should be avoided during and after harvest, as produce left out in the sun will gain heat and may become sun-burned (Lisa and Kader, 2003).

Directly following harvest pre-cooling is essential, any delay in cooling will shorten postharvest life and reduce quality. Night or early morning (when temperature is relatively low) harvesting is sometimes an option for harvesting produce, this reduces the energy needed for subsequent cooling. (Lisa and Kader, 2003). An Evaporative cooling system can be used to lower the storage temperature and also increases the relative humidity within the optimum level of the storage thereby keeping the fruits and vegetables fresh. Evaporative cooling occurs when

air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. It can be used for short term preservation after harvested. The Technology of evaporative cooling is cost effective and could be used to prolong the shelf-life of agricultural produce (Liberty *et. al.*, 2013).

### **7.3 Controlled/Modified atmosphere treatments**

Atmosphere control allows the possibility of slowing down metabolic processes, hence retarding respiration, ripening, senescence and the development of disorders. The aim is to introduce N<sub>2</sub> and remove O<sub>2</sub>, allowing a buildup of CO<sub>2</sub> (Alistair, 2006). For commodities that tolerate high CO<sub>2</sub> levels, 15 to 20% CO<sub>2</sub>-enriched air can be used as a fungistat to control decay-causing pathogens. Low O<sub>2</sub> and/or high CO<sub>2</sub> have been used to kill certain insects in commodities that can tolerate these conditions (Lisa and Kader, 2003).

### **7.4 Decay and insect control**

The first line of defense against insects and disease is good management during production. Planting resistant varieties, the use of irrigation practices that do not wet the leaves or flowers of plants, avoiding over-fertilization with nitrogen, and pruning during production to reduce canopy overgrowth can all serve to reduce produce decay before and after harvest. A second important defense is careful harvesting and preparation for market in the field. Thirdly, sorting out damaged or decaying produce will limit contamination of the remaining, healthy produce. Yet, even when the greatest care is taken, sometimes produce must be treated to control insects or decay-causing organisms (Lisa and Kader, 2003).

## 8.0 Conclusion

Postharvest losses in fruits and vegetables can only be reduced when pre and postharvest spoilage factors are fully identified. Preharvest factors such as production location, soil type, irrigation, rootstock, shading and nutrition are known to affect postharvest quality. Improper postharvest handling, transportation and storage can impose rapid deterioration in fruits and vegetables. Postharvest spoilage can be reduced by adopting good cultural practices, skillful harvesting, careful handling, good management of storage and transportation conditions, design of appropriate package and storage structures and use of permitted chemicals. Lack of adequate modern farming skills by local farmers and inadequate facilities for

postharvest handling and storage are responsible for postharvest spoilage of fresh fruits and vegetables in developing countries including Nigeria. Creating awareness among local farmers and use of modern and affecting farming techniques can overcome protracted postharvest losses resulting from preharvest factors. Techniques such as pre-cooling, appropriate packaging system, cushioning during packaging and transportation, careful handling to avoid mechanical damages, storage at ambient humidity and temperature and use of safe and effective artificial ripening methods must be adopted by local fruits and vegetables farmers and retailers in order to defeat postharvest losses, and also reduce glut of fresh produce.

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