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Relationship between Damages and other Postharvest Stress Factors Affecting Quality of Fruit and Vegetables

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ABSTRACT

Stress is the main concern hindering the maintenance of postharvest quality of fruit and vegetables. From production to consumption, fruit and vegetables are subjected to various handling activities in which some of these activities result in damaging commodity which make them susceptible to stress through entire post-harvest period. Stresses mostly come from biological and environmental factors such as harvest conditions, temperature, relative humidity, and gas composition of storage environment, as well as metabolic activities and microbial infections which all correlate with damages for one way or another and bring about quality loss and shortening of commodity's shelf life. While the most common type of damages arises during harvesting, handling and transportation is mechanical or physical damage, freezing, chilling and heat injuries are commonly occurred during storage from improper temperature management mainly for crops derived from subtropical and tropical growing regions. All these damages are believed to promote postharvest stresses and be the crucial cause of destruction of plant tissues and comprises total bruising, crushing and rupturing of fruit and vegetables during storage. Taking an example of mechanical damages, they influence respiration rates, ethylene production and loss of moisture in fresh produce and become more susceptible to microbial decay resulting in produce's quality losses during storage whereas, freezing and chilling injuries also induce much more other physiological disorders associated to oxidative stresses and the later cause immediate collapse of the tissues and total loss of cellular integrity, surface pitting, internal browning and accelerated softening and decay appearance in stored produce.

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Introduction

Stress is the main factor hindering the maintenance of postharvest quality of fruit and vegetables. Fruit and vegetables rely on the stored nutrients and continue to undergo different metabolic processes after harvesting which make them more susceptible to stresses throughout the entire post-harvest period. Stresses encountered during postharvest life of fruit and vegetables are mostly from biological and environmental factors such as harvest condition, temperature and relative humidity, microbial infections, gas composition of storage and mechanical damage among others resulting in quality loss and shortening of commodity's shelf life [1,2].

The main causes of short shelf life and quality loss of harvested fruit and vegetables are the physiological changes steadily take place within harvested produce during postharvest period which result in different oxidative stresses. Thus, a produce to respond to these stresses, it increases its metabolic activities and use of stored nutrients as way to self-defense and survival hence reduces its quality. The quality loss of many fruits and vegetables is highly linked to the development of postharvest disorder associated with oxidative stress such superficial scald, internal browning, loss of membrane integrity, tissue softening and shriveling, pigment color and nutrient contents of the produce during postharvest storage period [3,4].

The main processes controlling postharvest shelf life of fruit and vegetables known as respiration rate, ethylene production and weight losses are affected by environmental temperature, gas composition and relative humidity as main factors responsible for postharvest stresses. Under unfavorable storage environment like too high or too low temperature depending on a commodity, high or low relative humidity, unwanted gas composition in storage room, commodities are subjected to different damages such as Chilling, freezing, heat and mechanical injury and other oxidative damages [2,3].

Since stress may happen at any stage of postharvest handling from harvesting to the final consumer, with all these in mind, fruits and vegetables need to be handled carefully to reduce any injury that may occur. It is also worthy to determine the relationship between damages and other postharvest stress factors as a key for better management of these stresses to maintain postharvest quality of fruit and vegetables. Therefore, this work aimed at elaborating the correlation between different injuries encountered before, during and after harvesting and other stress factors during postharvest life of fruit and vegetables.

Damages/ Injuries and Their Implications

Damage or injury is one of limiting factors in maintaining the quality of fruits and vegetables and is also considered as a type of stress that affects the fruits and vegetables shelf life. Damages occur at any stages of commodity value chain from different sources. During harvesting, transportation and packing stage fruit and some vegetables are subjected to vibration, compression, impact or dropping that brings about postharvest stresses associated with mechanical damage such as rapid decay, microbial infections, bruising and total damage of produce. Harsh environment conditions during storage such as temperatures above or below optimum are subsequent to freezing, chilling and heat injuries and inappropriate relative humidity favors softening and decay development, incidence and physiological disorders of the produce [2,5].

Physical or Mechanical Damage/ Injury

Numerous sorts of injury may occur before, during and/ or after harvesting from different causal agent such as environmental conditions, insects, birds and farm handling activities. The implications of injury are different ranging from the increase in respiration rate and increased moisture loss to enhanced ethylene production depending on the type of commodity, incidence of injury and the period to which commodity last before being consumed. Mechanical damage can also arise from inappropriate harvesting, handling and transportation and storage activities lead to quality losses by inducing physiological and biochemical changes resulting to degradation of nutrients from increased respiration rate as observed in citrus fruit, a number of changes in taste, color, flavor, texture, and appearance take place in the harvested commodities, which make them unacceptable for consumption. Some of the chemical, physiological, and biochemical changes occurring during fruit ripening, handling, and transportation are the result of damage related to mechanical and textural properties of produce. Mechanical operations during harvesting and postharvest activities such as sorting grading, packaging and transportation are responsible for mechanical damage which results in the destruction of plant tissues and comprises total bruising, crushing and rupturing of fruits and the vegetables. Mecahnical injury also makes fruit more susceptible to pathogens' attack [2,6-12].

Compression and mechanical damages in citrus fruits increased respiration rates which are mainly attributed to microbial infection and development of rots during storage period. The rapid softening of tomatoes due to cell wall rupture from extreme stresses after compression and mechanical damage during storage period. Brushing, surface abrasions resulted from mechanical injuries can accelerate loss of water and vitamin C and increase susceptibility to decay. The increase in respiration rate and weigh loss of fruit weight were also observed in pomegranates as results of bruise damage. Banana subjected to abrasion, cutting, impact and compression damage appeared to have a faster conversion of starch into sugar indicated by their high respiration rate and ethylene production during storage period resulting in weight loss and reducing postharvest shelf life. The production and marketing of stone fruits (apricots, cherries, nectarines, peaches and plums) has enlarged promptly, however damages vibration or abrasion bruising occurred during harvesting, handling and transportation lead to color change of the fruit, accelerate water loss, favor pathogen penetration and quality loss. Thus, care should be taken while handling those fruit to maximize profit. The compression of sweet cherry fruit resulted in an elevated ethylene production, even though sweet cherry as non-climacteric because does not exhibit an ethylene associated respiratory peak. Physical damaged cherries exhibit high respiration rate, loss of moisture and become more susceptible to microbial decay resulting in surface decay and quality losses during storage. The similar result was observed in apricots whereby impact injury fastened browning just after 3 days of storage, enhanced softening and reduce the storage period [7,12-18].

Freezing Injury

All commodities are subject to damage when exposed to extremes of temperature. They also vary considerably in their temperature tolerance. The levels of tolerance to low temperatures are of great importance for cold storage. Freezing injury is a type of stress caused by low temperature. In general, higher temperatures during storage increase the rate of metabolic activities thereby reducing the shelf life of stored commodities, thus reducing temperature during fruit and vegetables storage became one of better treatment to increase fruit and vegetables shelf life. Nevertheless, low temperatures during storage put rate of metabolic activities under control and bring about prolonged postharvest shelf life of fruit and vegetables too much lower temperatures may lead to different stresses such as freezing or chilling injury in resulting in quality losses of the stored commodities. Some fruit and vegetables freeze at just below 0°C (ranging from –3°C to –0.5°C). Freezing damages cells and induces the contents to leak out which usually results in immediate collapse of the tissues and total loss of cellular integrity and decay appearance [5,19,20].

Table 1: Example of Damages and their Physiological Implications in Some Fruit and Vegetables

Type of Commodity	Damage	Physiological disorders caused and their implications	References
Banana	Cutting and Abrasion	Physical and metabolic alterations resulting in increased weight loss, accelerated color change and increased ethylene production and activities of starch degradation enzymes	[15]
Pomegranates	Bruising	Enhanced fruit respiration rate and weigh loss with respect to drop impact and storage temperatures	[14]
Sweet cherry	Physical damage (dropping and compression)	Increased respiration rate with an elevated ethylene production rate and microbiological decay	[17]
Citrus Fruits (Tangerines, limes, and oranges)	Compression and impact mechanical damages	Enhance susceptibility to internal quality losses during storage such as loss of ascorbic acid contents (vitamin C) and Increases respiration rate as indicated by increased CO_2 production	[7,21,22]
Apricots	Impact injury	Compression force enhances fruit browning and softening	[18]
Peaches and Nectarines	Physical damage (abrasion)	Damage induces brown and/or black spots resulting in skin discoloration	[16,23]

Chilling Injury

The temperature abuse during postharvest handling of fruit and vegetables is an ongoing challenge for many products. Low temperature stress known as chilling injury susceptibility is a significant issue for many crops derived from subtropical and tropical growing regions. Commodities respond unfavorably to storage at low temperatures well above their freezing points, but below a critical temperature between 5 and 13°C. Surface pitting, internal browning and accelerated softening often associated with chilling injury. Sometimes the symptoms of chilling injury might not be seen at low temperature during storage but when the products reach market where temperature is high, the symptoms of chilling injury start to appear that is why these symptoms can be mistaken as those associated with pathogens and ripening action. Chilling injury is a mere cause of failure to ripen in banana and development of off-flavors in tomatoes, development of pits or sunken areas in oranges, melons and cucumbers, brown discoloration in avocadoes and eggplants, and increased susceptibility to decay in cucumbers and beans. Plums stored at low temperature increases ethylene production as response to stress caused by chilling injury at low temperature generally below 5°C for most cultivars. Peaches and nectarines are more susceptible to decay when stored at ambient temperature, therefore cold storage is preferred for this fruit. However, too low temperature makes them subjected to chilling injury which then induce other physiological disorders. Storage of peaches at low temperature between 2.2- 7.60C results in chilling injury which later on induces browning and reddening or bleeding of the fruit associated with fruit response to oxidative stress. The effects of chilling injury are the results of increased reactive oxygen species like superoxide anion $O2^-$, Hydro peroxide H_2O_2, and Hydroxyl radical which cooperates with ethylene actions. This intrerraction brings about water loss, weight loss, flavour loss, surface pitting, internal browning, textural changes, softening, mealiness, flavour loss and shorter postharvest shelf life in fruit [5,11,24-31].

Heat Injury

High temperatures are also very injurious to perishable products. High temperature above optimum 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 of the commodity. The experiment done in apricots showed that injured fruit keep at low temperature (4^0C) and kept at room temperature (18^0C) showed greater metabolic activities than that kept at low temperature after subjected to injuries even though after some days of storage those with injury stored in low temperature showed an increase in ethylene production compared to those without injury [5,18].

Table 2: Effects of Temperature Stresses on Quality of Some Fruit and Vegetables

Type of commodity	Temperature	Injury and its implications	References
Peaches and Nectarines	2.2- 7.6°C	Chilling injury induces browning and reddening, woolliness and decay of fruits	[28,29]
Cherries	0 to 4°C	Cold temperature injury induces fruit softening and water losses	[32]
Plums	Below 5°C	Chilling injury increases ethylene production as response to low temperature stress	[11]
Apricots	18°C	Heat injury enhance metabolic activities in injured fruit keep at low temperature (40C) and kept at room temperature (180C)	[18]
Tomatoes	Above 20°C	higher storage temperature resulted in increased ethylene production resulting into tomato weigh and quality loss	[33]
Cucumber	Below 10°C	Chilling injury induces water-soaked areas, pitting and accelerated decay. Freezing injury is also initiated at -0.5°C which is also characterized by a water-soaked pulp becoming brown and gelatinous in appearance over time	[34]
Melons	Below 4ºC	The low temperatures cause the loss of the pulp's red color. Chilling injury causes brown spots in the rind and a bad taste in watermelons	[26,35]
Eggplants	0ºC	Chilling injury occurs and encourages oxidation potential leading to browning of the pulp. This may be related to the anthocyanin function in response to active oxygen species (AOS)	[36]
Mango	Below 10-13 ºC	Chilling for mango triggers grayish, scald-like discoloration on the skin, followed by pitting, uneven ripening, and poor flavor and color development and accelerated the softening of the fruit and increased susceptibility to microbial spoilage	[37]

Injuries and Atmospheric Gas Production

Ethylene is one of gases released by fruit and vegetables due to injury, decay or during ripening. The exposure of fruit and vegetables to this gas results in yellowing, shortened shelf life and increased disease. Ethylene production is awakened by many factors including mechanical injury as observed in different studies. Impact injury stimulates apricot ethylene production during storage period. While damage like mechanical injury induce ethylene production during storage,some measures have developped to reduce metabolic activities associated with ethylene producrtion. Some of these measures in cold and low oxygen storage. Low temperature together with low 02 level reduce the incidence of injury during storage. The exposure of peaches to low O_2 atmospheres and 5°C of storage for 3 days reduces respiration and ethylene production rates and delays incidence and reduces severity of internal breakdown (chilling injury) and decay[18, 38-40]

Conclusion

After harvesting, Fruit and vegetables rely on stored nutrients for all their metabolic activities without replenishment of the nutrients which makes them more subjected to stress during their postharvest shelf life. This makes stress management the most challenging issue to maintain the quality of fruit and vegetables. Stress can be delivered from the natural ageing process of commodity associated to respiration and ripening and senescence or from damages caused during commodity value chain. Damages encountered before, during and after harvesting as well as those occur during handling, transportation and storage govern postharvest life of fruit and vegetables thereby inducing various disorders and enhancing other postharvest stress factors. The incidence and severity of stresses are directly controlled by factors like harvest conditions, temperature and relative humidity, microbial infections, gas composition of storage and damages. Mechanical injury from vibration, compression, impact or dropping occurred during commodity value chain is one of serious damages that triggers much more physiological disorders in fruit and vegetables during storage. Some of the implications damages as reported by different researchers includes but not limited to increased respiration rate and ethylene production, changes in taste, color, flavor, texture, and appearance of a stored commodity. A part from mechanical or physical injury there are other injuries from temperature management known as freezing, chilling and heat injury.

These injuries also have a great contribution to fruit and vegetables quality loss as that caused by mechanical damages. All those damages can induce oxidative stresses and the produce to respond to these stresses, it increases its metabolic activities such as increased respiration rate and ethylene production resulting in rapid senescence, susceptibility to microbial infections and decay, weight loss and total quality loss of stored commodity. As damages may occur at any stage, from harvesting to final consumer, all handling and storage activities should be done carefully together with better management of temperature, relative humidity and of atmospheric gas compositions of in storage environment to maintain the quality of fruit and vegetables.

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