Harvest and Postharvest Deteriorating Factors of Cucurbits and Avoidance Techniques :A Review

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Summary

Improving cucurbit vegetables storability starts in the field by the appropriate selection of the cultivars gown. Harvesting at the most appropriate stage according to consumer preference and shipping distance and duration are also advisable. Minimizing crop physical damage and sanitation after harvest improve cucurbits storability. Cooling directly after harvest, using the most suitable pre-cooling method, followed by holding at the most appropriate temperature for each crop is required. Cucurbits should be stored or shipped, directly after being pre-cooled. Since cucurbits are chilling sensitive, temperature during shipping or storage have to be always above freezing, but slightly higher than crop threshold temperature to avoid fruit chilling injury (CI). Precise adjusting and monitoring of temperature and RH while storing or shipping with good ventilation extend cucurbits storage life. Avoiding crop mixing during storage or shipping, particularly ethylene-producing cucurbits with those sensitive to it, is extremely important. Ethylene removal, oxidizing or inhibition during storage, therefore, is recommended. Several pre-storage treatments are proposed to reduce cucurbits chilling sensitivity (CS). These treatments include fruit conditioning, heat treatment, short anaerobic conditioning and Ca^{2+} dipping. In addition, pre-storage ethylene treatment, for ripeconsumed cucurbits, or re-warming during cold storage reduced fruit CS. Storing under modified or controlled atmosphere (MA or CA), or under low-pressure storage (LPS) are also other tools that are used for reducing cucurbits CS and for storability improvement.

Keywords: Cucurbits; Postharvest handling; Deteriorating factors; Storability; Supplementary treatments.

Introduction

Cucurbits belonging to the family *cucurbitaceae* are vegetables consumed for their fruits either immature or at full-ripe stage. Fruit genus, species or variety as well as consumer habit or preference play an important role in determining the stage of fruit consumption (Hardenburg *et al.,* 1986 and Nonnecke,1989). Cucumber, squash and snake cucumber are clear examples for immature-consumed cucurbits. Regardless of being members of the same family, watermelon, pumpkins and melons including cantaloupe, honeydew, crenshaw, casaba, persain, sweet melons and European cantaloupe are consumed only when they reach full-ripe stage (Nonnecke, 1989). These variabilities in the stage of cucurbits consumption (Table 1), created greater differences in their postharvest handling. The storability oicucurbits relies on several harvest and postharvest factors. Fruit storability (Ells and McSay, 1981). PosUiarvest internal (i.e., respiration, C_2H_4 production, sensitivity to Cl,...etc.) deteriorating factors which directly affect the storability of cucurbits (Kader, 1985 and Kanellis *et al.,* 1986).

This article addresses cucurbits deteriorating factors at and after harvest. It also presents the treatments required to slow down such deteriorating factors tor improving cucurbits storability while maintammg local and international quality standards.

General Classification of Cucurbits Deteriorating Factors

Harvest and postharvest deteriorating factors of cucurbits are sequential factors (Diagram 1) that start in the field and increase during product harvesting, handling, transport, storing and marketing (Kader, 1985). Such factors end when the product is consumed. To alter these deteriorating factors, a sequential order of treatments has to be applied. Harvest and postharvest deteriorating factors of cucurbits, therefore, need to be clearly and accurately identified to address the required treatments in an order which can enable growers, harvesters, handlers, traders, investors, exporters and even consumers to overcome. The required treatment(s) for slowing down such deteriorating factors are discussed.

1. Deteriorating Factors at Harvest and Treatments for Avoidance

There are several deteriorating factors requiring prompt treatment just prior or at harvest as well as directly after harvest. Due to the increased magnitude of these factors surrounding the harvest process on cucurbits storability, it is appropriate to handle these factors as "at harvest factors" since the overall quality of these crops rely mainly on the related treatments required to slow down such fast deteriorating factors.

1.1. Harvesting stage, method and time

Beside crop taxonomy and consumer habit and preference, there are also several factors affecting cucurbits harvesting stage. These factors include product end use (fresh market or processing) and marketing or shipping distances and duration. Pickling cucumoer fruits are harvested at earlier immature ages as compared to those picked for fresh consumption (Eills and McSay, 1981). For export however, cucumber anasummer squash fruits are harvested at larger sizes as compared to those harvested for local market supply based on consumer preference (Kanellis *et al.,* 1986). In an opposite trend, melons (i. e., cantaloupe and honeydew) are harvested at late maturity or at early ripe stage for export, but at full-ripe stage for local market (kader, 1985). Due to the difference between immature and ripe-consumed cucurbits, their recommended harvesting stages will be presented separately.

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Abbreviation : ACC, 1-aminocyclopropane-1-carboxylic acid; CA; controlled atmosphere; CI, chilling injury; CS; chilling sensitivity; LPS, Low pressure storage; MA, modified atmosphere; RH, relative humidity.

Table 1. Classification of cucurbits fruits harvesting stage according to crop taxonomy.

Genus	Species	Botanical variety	Crop	Harvesting stage
Cucumis	*sativus*		Cucumber	Immature
	melo	Flexuosus [X]	Snake cucumber	Immature
		Chate	Orange melon	Ripe
		Reticulatus [Y]	Cantaloupe [Z]	Ripe
		Inodorus	Honeydew, Casaba,	Ripe
			Crenshaw, Persain	Ripe
		Cantalupensis	European cantaloupe	Ripe
		Aegyptiacus	Sweet melon	Ripe
Cucurbita	*pepo*		Summer squash	Immature
			Winter squashes	Ripe
			& Pumpkins	Ripe
	moschato, maxima		Winter squashes	Ripe
	& argyrosperma		& Pumpkins	Ripe
Citrullus	*lanatus*		Watermelon	Ripe

X Elongatus and pubescence are other varieties of snake cucumber.
Y Variety of vine-slip fruit with ripening initiation and progress.
Z Misnomer crop since it belongs to reticulatus not cantalupensis botanical variety
From Nonnecke (1989)

A. Immature-consumed cucurbits

The storability of immature-consumed cucurbits relies mainly on postharvest chlorophyll degradation and water loss (Kader, 1983 and Kanellis *et al.*, 1986). Fruit harvested at younger immature ages exhibit higher rates of respiration, C_2H_4 production, water loss and chlorophyll degradation and were faster in senescence than those harvested at older immature ages (Kader, 1983 and Kanellis *et al.*, 1986). Precise detection of harvesting stage is one of the key factors controlling immature cucurbits storagbility. In addition, several treatments can be applied immediately after harvest (i.e., pre-cooling, sanitizing, Ca^{2+} dipping, fruit wraooing or waxing, ...etc) while other treatments should be applied during storage or shipping (i.e., controlling of temperature, RH, respiration, C_2H_4 production and\or action,...etc.) for improving the storability of immature cucurbits.

B. Ripe-consnmed cucurbits

For long distance distribution or for export, cantaloupe, honeydew and watermelon are harvested at an advanced stage of maturity and before reaching full-ripe stage (Kader, 1983). Maturity detection can easily be determined in cantaloupe but not in honeydew and watermelon if morphological aspects are used as references. Fruit surface netting and the well-developed abscission layer are clear morphological aspects for cantalonpe maturation. These morphological aspects are absent in honeydew and watermelon (Kader, 1985). Other morphological aspects, therefore, can be used, out still in-accurate, such as ground colour change in honeydew (Suslow *et al.*, 1991) and senescing of the tendril closest to the fruit attachment in watermelon (Corey and Schlimme, 1988). For more accurate maturity detection several non-destructive techniques are now being developed. These techniques are magnetic resonance imaging (Clark *et al.*, 1997), near infrared analysis of soluble solids and measuring fruit level of G_2H_4 production. (Miccolis and Saltveit, 1991). The most importantpararneter by which melons harvesting stage can be accurately determined is fruit sweetness (McCollum e*t al.*, 1988). Melons, including watermelon, nave no starch reserves and the sugar content does not increase after harvest. For good flavored melons and longer storage life with high consumer acceptance, it is critical to harvest at a sufficiently advanced stage when sugars have already been accumulated in the iruit (Cantwell, 1996 and Suslow *et al.*, 1997). Melon maturity is the most important factor determining fruit keeping quality during storage (McCollum *et al.*, 1988). As it has been previously stated, cantaloupe and other netted melons (var. Reticulatus) criteria for harvest is the formation of fruit abscission layer which is called slip. Based on marketing and/or shipping distances, cantaloupe fruits can be harvested at different slip degrees. For tong distance shipping, 1/4 or 1/2 slip is recommended but 3/4 slip is the most suitable stage for air shipping or nearby markets. Full-slip stage however, is the most common harvesting stage for local market supply (Kader, 1985).

In terms of harvesting methods or techniques, cucurbits are mainly hand-picked. The most important factor that has direct impact on the storability is mechanical damages at harvest (Kader, 1983 and Yang, 1980). After picking, fruits must be placed in shade to avoid more field heat load. Packing in the field containers has to be carefully monitored to prevent fruit dropping, scratching, bruising, abrasions,...etc.

Harvesting time during the day is also among the factors affecting cucurbits storability (Kader, 1983). Early morning is the most advisable time for harvest. Increasing fruit temperature in the field wim harvest delay will accelerate fruit deterioration and reduces its postharvest life. Fast cooling is also required since the time between harvest and cooling is the most important factor affecting cucurbits storability (Cantwell, 1996 and Suslow *et al.*, 1997).

1.2. Field handling, physical damages,packages, packing and transport

Mechanical injury is a leading cause ior postharvest quality loss. It is a cumulative factor as it occurs at harvest, handling and packing operations. Cucurbits pass through several postharvest transfer points, and each transfer point has its potentialto reduce quality by causing injuries such as bruises, cuts, punctures, abrasions and scuffing. Injured tissues have a greater tendency to lose water and are more likely to serve as entry sites for pathogens. The positive impact of mechanical injuries on G_2H_4 production and respiration has been reported to cause fruit fast deterioration, rotting and senescence (Yang and Horfman, 1984). Corrugated carton containers are the most common package used for cucurbits. Based on cucurbit species, fruit size and shape, different types of packages can be used. Larger containers are commonly used for cucurbit fruits of larger siz-

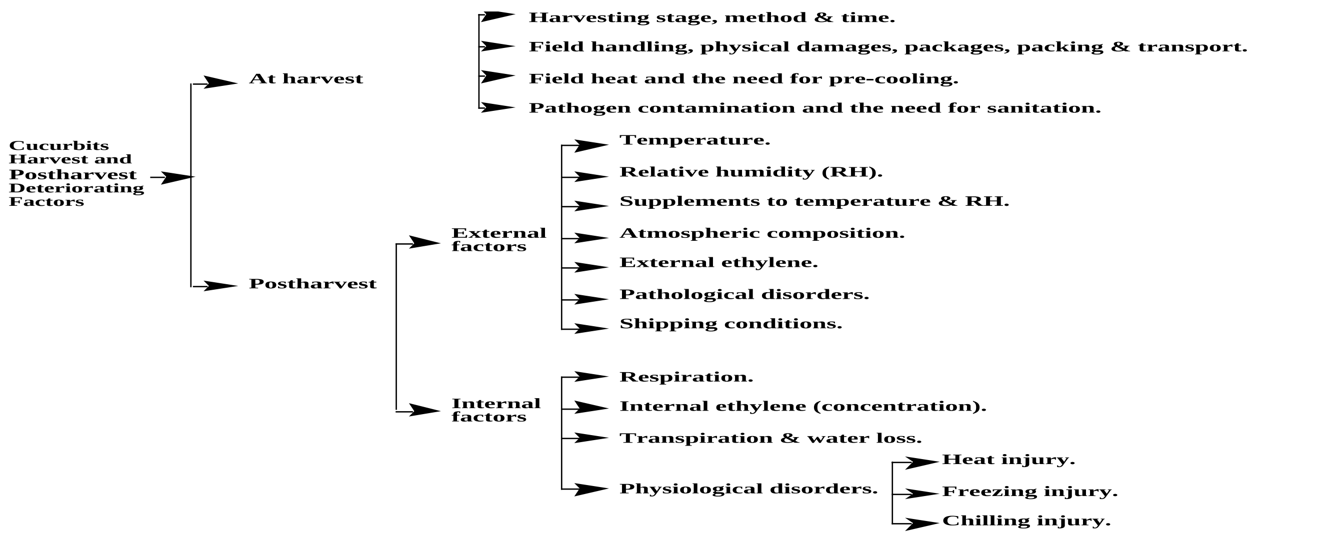

Diagram 1. Classification of cucuirbits postharvest deteriorating factors.

es (i. e., watermelon and pumpkins). Also, it is common to pack certain cucurbit species with fruit counftpack. In all cases, package diminutions must be carefully adjusted to accommodate the mass of packed fruits without over-filling. At pacling, care has to be paid for preventing product immobilization within the container. With product lateral tigntening within the con- tainer and good staking while palletizing and loading, fruit compression, vibration and abrasion bruises can be avoided (Kader, 1985).

1.3. Field heat and the need for pre-cooling

Temperature is the single most important factor in the total postharvest environment that adversely affects harvested crops. It directly affects the rates of respiration and the production of vital heat, ripening and the production of G_2H_4 and other volatiles, moisture loss, and spread of decay as well as senescence enhancement. The delay in time between harvest and cooling is the major cause of product quality loss and postharvest life reduction (Kasmire, 1978). It is well known that the faster to cool after harvest the longer the commodity can be stored with optimal quality maintenance. Methods used for pre-cooling are room cooling, forced-air cooling, hydrocooling, ice-topping or mixing, vacuum-cooling and hydro-vac-cooling (Kasmire, 19/8). It is well known that hydrocooling ana ice-topping or mixing are the fastest pre-cooling methods followed by forced-air cooling wnile room cooling is the slowest one. Vacuum and hydro-vac-cooling are not advised for cucurbits (Cantwetl, 1996 and Kasmire, 1978 and Suslow *et al.,* 1996) since these methods require crops with large surface to weight ratio (e.g. leafy vegetables). It is recommended, therefore, to use forced-air cooling for all cucurbits. In addition, hydrocooling and package-icing can be used for cantaloupe if forced-air cooling is not available or faster cooling is deeply required (Cantwell, 1996 and Kasmire, 1978). With hydrocooling, lowering water specific heat is required to increase cooling speed. This can be achieved by adding table salt to the water used for hydrocooling. Cooling followed by holding at proper temperature helps in improving cucurbits storability and control ripening of fruits harvested at repining onset such as cantaloupe (Kader, 1992).

1.4. Pathogen contamination and the need for sanitation

The presence of numerous genera of spoilage (bacteria, yeast and molds, and an occasional pathogen) on fresh produce has been recognized for many years. Several outbreaks of human gastroenteritis have been linked to the consumption of contaminated fresh vegetables. Microorganism's contamination may be loaded on the fruits in the field or by harvesters, handlers or packers or by the water used for washing.

As a sanitizing agent or disinfectant, chlorine was introduced 60 years ago as a drinking water disinfectant (Carlson, 1991). Elemental chlorine and hypochlorites have been used for many years by the food industry for sanitizing equipment, utensils, surfaces, fruits and vegetables. The additions of chlorine gas or chlorine compounds to the water used for washing are the most common technique used for fruits and vegetables sanitation. Sodium or calcium hypochlorite has round broad application in washing and decontamination of fresh fruits and vegetables. Hypochlorite salts are effective in killing bacteria, fungi, viruses and nematodes on fresh food and are advised to be supplemented to the washing water and to the cold water used for hydrocooling (Kader, 1992).

2. Postharvest Deteriorating Factors and the Related Techniques and Treatments for Avoidance

2.1. External postharvest factors

2.1.1. Temperature

Temperature is the most environmental factor influencing the deterioration rate of harvested commodities. It directly affects the rates of respiration, C_2H_4 production, moisture loss, decay spread and senescence acceleration, for each increase of $I^{O}C$ above optimum, the rate of deterioration increases by two to three folds. Holding at temperature higher than that recommended will increase cucurbits respiration causing faster depletion of their nutritive values. Ethylene production will also increase resulting in higher levels of chlorophyll loss (reduction immature-consumed cucurbits quality and storability), ripening acceleration (shorter postharvest life) and senes-cence enhancement. It will also increase product moisture loss, shrivelling and fresh appearance loss. High temperature will increase pathogen growth and activity causing fast fruit decay. Excess increases in the holding temperature will enhance fruit heat injury (Hardenburg *et al.*, 1986). Temperature management is the most effective tool for extending the storage-life of cucurbits. It begins with the rapid removal of field heat followed by holding the product at the most recommended temperature. Due to .cucurbits sensitivity to Cl (McCollurn and MeDonad,1991), they have to be stored at temperatures higher than ^{O}C. Each cucurbit crop has its own recommended storage temperature as presented in Table (2). In addition to the required storage temperature, commodities should be staked in the cold room leaving air spaces between pallets and room walls to ensure good air circulation. Commodity temperature must be monitored rather than air modity temperature. Maintaining proper temperature and RH for each crop must be considered throughout all handling steps.

Table 2. The optimal storage conditions (temperature and RH) for cucurbits and their approximate storage life under such conditions.

Cucurbit crop	Temp. (°C)	RH (%)	Storage life
Cucumber	10-13	95	10-12 days
Summer squash	5-10	95	7-12 days
Cantaloupe (3/4 slip) X	2-5	95	15 days
Cantaloupe (full slip) X	0-2	95	5-14 days
Honeydew	7	90-95	3 weeks
Crenshaw	7	90-95	2 weeks
Casaba	10	90-95	3 weeks
Persian	7	90-95	2 weeks
Watermelon	10-15	90	2-3 weeks
Winter squashes	10	50-70	2-3 months
Pumpkins	10-13	50-70	2-3 months

X American cantaloupe.
Summarized from: Cantwell, 1996; Salunkhe and Desai, 1984; Suslow *et al.*, 1997.

2.1.2. Relative humidity (RH)

The rate of water loss depends upon vapor pressure deficit between commodity (fruits and vegetables) and surrounding ambient air, which is influenced by temperature and RH. At a given temperature and rate of air movement, the rate of commodity water loss depends on ambient RH. Also water loss increases with the increase in temperature at a given RH (Kader, 1992). (cucurbits vary in their required RH during storage, as all cucurbits require high RH except pumpkins and winter squashes (Table 2). RH can also influence decay development, incidence oisome physiological disorders and unilormity of fruit ripening. Condensation of moisture on the commodity (sweating) over long periods of time is probably more important than is the RH of ambient air in enhancing product decay. One or more procedures canoe used to control stores RH such as the use of humidifiers, water wetting of store floor, regulating stores air movement, ventilation, maintaining the difference between refrigeration coils and air temperature within I^{0}C, good store insulation and product packing in plastic films.

2.1.3. Supplement treatments to temperature and humidity management

Many technological procedures are commercially used as supplements to temperature management. None of these procedures, alone or in their various combinations, can suostitute for maintenance of optimum temperature and RH, but they can help in extending the storage-life of harvested fruits beyond what is possible using refrigeration alone. As described below, several supplementary treatments can be applied for cucuroits storability improvement.

2.1.3.1. Heat treatment

Postharvest heat treatment is now commercially used for postharvest non-chemical decay control (Barkal Golan and Phillips, 1991) as well as for reducing cucurbits CS (Lester *et al.*, 1988 and Wang, 1993 and 1994). Postharvest heat treatment to control decay is often applied at temperatures above 40 ^{o}C for only 3-5 minutes since the targeted pathogens are usually found on the surface or within the few outer-cell layers of the fruit. Fruits and vegetables commonly tolerate temperatures of 50-60C for 5-10 minutes, but shorter exposure controls many postharvest pathogens (Barkal-Golan and Phillips, 1991). This temperature range and treatment duration is also recommended for reducing cucurbits CS (Teltel *et al.*, 1989 and Wang, 1994). Heat is usually delivered to the commodity by air or water. Heated moist air usually kills pathogens more effectively than dry air at the same temperature. Wnen hot water is used a minimum cornmodity-to-water ratio of 1:10 can result in satisfactory surface heating (Barkal-Golan and Phillips, 1991). Dipping cantaloupe (Teltel *et al.*,1989), cpcumber (McCollnm and McDonald, 1993) or summer squash fruits (Wang, 1994) in hot water of 52^{o}C for 2 min, 42^{o}C for 30-60 min or 42^{o}C for 30 min, respectively, considerably reduced fruit Cl. The increase in polyamine biosynthesis, as a result of postharvest heat treatment, has been proposed to enhance the stabilization of membranes and reduces fruit CS (Wang, 1994).

2.1.3.2. Treatment with postharvest fungicides

Fungicides and bactericides that effectively reduce decay are beneficial supplements to some cucurbits during refrigerated storage. Fungicides are often applied with cleaning or waxing operation. Benomyl, thiabendazole, 2-aminobtan and imazalil are good examples tor the commercially used fungicides (Hardenburg *et al.*, 1986 and Risse and Hatton, 1982). Hot water containing fungicides is more effective than water or fungicides alone. The mechanism of control with heated fungicide mixes may be related in part to the direct effect of heat or to the increased chemical activity, but control may also be improved by increased penetration and deposition of fungicide on the product when solution is heated (Barkal-Golan and Phillips, 1991).

2.1.3.3. Special chemical treatments

Calcium plays a pivotal role in controlling many pre and postharvest physiological disorders in fruits and vegetables. It is the only element, which is advised to be applied to cucurbits and other horticultural crops before and after harvest. The relation between Ca^{2+} and fruit cells membrane stability has been markedly established (Lester,1995 and Minorsky, 1985). Postharvest dipping in Ca^{2+}, therefore, delayed fruit senescence and improved fruits and vegetables storability (Lester,1995 and Minorsky,1985). Fruit respiration (Haks, 1985 and Poovaiah, 1985) and C_2H_4 action (Yang, 1980 and Yang and Hoffman, l984) and sensitivity to Cl (Lester, 1995 and Minorsky, 1985 and Poovaiah,1985) are also altered witn postharvest Ca^{2+} application. MA, CA and C_2H_4 treatment or removal are other supplements to temperature ana humidity management, but they will be discussed separately.

2.1.4. Atmospheric composition

Changing fruit ambient atmospheric composition is used, in several crops, to improve the storability and to slow down quality loss. The use or MA and CA atmospheres mean reduction of O_2 and / or elevation of CO_2 concentrations out they differ only in the degree of control since CA is more exact. In cucurbits, the use of MA or CA is commercially limited (Hardenburg *et al.*, 1986). The most recommended O_2 and 002 levels are 3-5 and 10-15% in cantaloupe, 3-5 and 10% in cucumber and honeydew, respectively. (Kader, 1992). Quality of cantaloupe stored in CA (10% CO_2 plus 10% O_2) with C_2H_4 absorbent for 14 days at 6C and an additional 6 days at 20°C was significantly higher than that of control or fruit stored in CA only (Aharoni *et al.*, 1993). MA and CA supplements to proper temperature and RH slow down fruit respiration, C_2H_4 production and action, softening, compositional changes and senescence and also reduce fruit sensitivity to Cl.

Hypobaric or low-pressure storage (LPS) is another sort of CA since reducing the total pressure, under partial vacuum conditions results in O_2 reduction and C_2H_4 removal. LPS has some advantages over other methods of atmospheric modification. These advantages are more exact O_2 concentration and removal of C_2H_4 (Kader, 1992).

2.1.5. External ethylene

Ethylene accelerates fruit senescence and markedly shortens its storage-life. It enhances chlorophyll degradation and fruit respiration, which adversely affect immature-consumed cucurbits storability (Kader, 1985 and 1992). Fruit ripening, softening and senescence are also induced by C_2H_4, which also limited ripe-consumed cucurbits storability (Yang and Hoifrnan, 1984). Immature-consumed cucurbits (Hardenburg *et al.*, 1986 and Salunkhe and Desai,1984) and watermelon (Risse and Hatton, 1982) are very sensitive to exogenous C_2H_4. A few methods can be used to remove C_2H_4 from cold stores such as ventilation, C_2H_4 absorbers (i. e., potassium permanganate alone or in combination with activated and brominated charcoal) and CA, MA or LPS (Aharoni *et al.*, 1993 and Yang and Hoffman, 1984). Oxidizing C_2H_4 using active oxidizers such as ozone (O_3) or atomic oxygen (O) can also be used (Kader, 1992 and Yang and Hoffman, 1984).

The use of ethylene to enhance fruit ripening and ripening uniformity is thoroughly documented. It is used commercially to promote faster and more uniform ripening in cantaloupe, honeydew and casaba. After the required period of cold storage or cold shipping, C_2H_4 can be used not only to enhance ripening but also to ensure ripening uniformity. Ethylene can be applied as a gas or by C_2H_4 releasing chemicals such as ethrel (Yang and Hoffman, 1984).

2.1.6. Pathological disorders

One of the most common and obvious symptoms of deterioration is that results from bacteria and fungi activities. Attack by most organisms follows physical injury or physiological breakdown of the commodity. In general, fruits and vegetables exhibit considerable resistance to potential pathogens during most of their postharvest life. Fruit ripening and senescence renders them susceptible to infection by pathogens. Stresses such as mechanical, chilling and sunscald injuries, reduce fruit resistance to pathogens. Minimizing physical injuries and avoiding chilling temperatures can arrest or at least minimize pathologicaFdisorders (Hardenburg *et al.*, 1986).

2.1.7. Shipping conditions

Several transportation methods are used to move fresh crops from shipping points to destination markets. Airplanes, railroads, ships (marine), trucks and combinations, such as trailer-on-flat car (TOFC) and container-on flat car (COPC) are all used to transport fruits and vegetables (Kasmire and Ahrens, 1992). The most important consideration is to cool commodity before loading since refrigerated trucks do not cool commodity but can retain the commodity loading temperature. For monitoring shipment temperature, measuring temperature of returned circulated air in the refrigerated trucks or containers is more accurate than measuring temperature of discharge air since the returned air is almost at the same temperature as the product (Kasmire and Ahrens, 1992). Air circulation while shipping is essential for cooling and for air exchange uniformity. Ballets, therefore, must be arranged with air gabs to allow good air circulation. This will help in avoiding heat transfer from outside with no building up of commodity produced gases.

It is also important not to ship C_2H_4-producing commodities such as cantaloupe, honeydew, casaba, crenshaw and persian witn C_2H_4 sensitive ones such as cucumber, summer squash and watermelon (Elkashif *et al.*, 1989). Temperature adjustment and management while shipping is extrmely important, particularly with mix shipping. American cantaloupe can be shipped at temperature as low as 2.5-5°C while 7°C is the most recommended temperature for honeydew, crenshaw ana persian. On the other hand, cucumber, summer and winter squashes, pumpkins and watermelon can not be shipped at temperature lower than IOC (Hardenburg *et al.*, 1986 and Wang, 1995). In marine and railroad transport, MA and CA can be used (Kasmire and Ahrens, 1992). In air shipping however, precise pre-cooling is deeply required. Re-cooling may also be required at final air shipping destination (Kasmire and Ahrens, 1992).

2.2. Internal postharvest factors and treatments for avoidance

2.2.1. Respiration

Respiration is the process by which stored organic materials in the fruit (mainly simple acids and sugars) are broken down into simple end products (CO_2 and H_2O) with O_2 consumption and energy (vital heat) release. The loss of stored food reserves (luring respiration means hastening of senescence, reduction in the nutritive value, loss of flavor and quality, particularly sweetness of ripe-consumed cucurbits. The energy released as heat affects postharvest technology considerations such as estimation of refrigeration and ventilation requirements (Kader,1992). Postharvest deteriorating rate is generally proportional to the respiration rate. Data presented in table (3) show cucurbits storage-life under optimum storing conditions in relation to their respiration rates. Immatureconsumed cucurbits are characterized by high respiration since they are still in their early stages of development. A fast postharvest drop in respiration is obtained uue not only to the high levels of fruit respiration at such harvesting stage but also to the limited content of fruit respiration substrates. This postharvest dramatic drop in respiration of immature cucurbits is slightly eliminated in ripe-harvested cucurbits which contain higher levels of sugars. When harvested at mature or at ripening onset, a substantial increase in respiration is obtained due to fruit climacteric behavior as in the case of melon fruits belonging to reticulatus and inodorus varieties (Cantwell, 1996 and Kader,1992).

Table 3. Respiration rates of cucurbits and their approximate storage life at the optimum storage temperature.

Cucurbit crop	Optimum storage temp. (°C)	Respiration rate (mg CO_2/kg.h)	Approximate storage life
Summer squash	5-10	24-48	7-14 days
Cucumber	10-13	24-31	10-14 days
Cantaloupe) X	2.5-5	9-10	2 weeks
Honeydew	7	5-7	3 weeks
Watermelon	10-15	5-7	3 weeks

Storage periods of winter squash and pumpkins (lower respiration rates) exceed 2-3 months at desired temperature.
X American cantaloupe. Summarized from: Hardenburg *et al.*, (1986).

Cucurbits respiration significantly increases when exposed to stress conditions such as mechanical or chemical injury as well as all nn-balanced environmental conditions. Minimizing such stresses are the key factors for reducing cucurbits respiration aiming for storability improvement. In addition to cold storage, MA, CA and LPS techniques as well as fruit waxing, wrapping, package lining, ...etc., are supplementary tools for more respiratory control.

2.2.2. Ethylene production

Ethylene is a natural plant hormone produced by all tissues of higher plants and by some microorganisms. Its produced in three types; basal, autocatalytic and stresses (Yang, 1980 and Yang and Hoffman, 1984). Basaf C_2H_4 is naturally produced by all plant tissues in parts per billion. This basal C_2H_4 plays an important role in fruit growth and development (Atta-Aly *et al.*, 1999). Autocatalytic C_2H_4 is produced in parts per million only in the fruits exhibiting climacteric behavior such as melon fruits belonging to reticulatus and inodorus varieties, while other cucurbits are non-climacteric ones (Elkashif *et al.*, 1989 and Hardenburg *et al.*, 1986). The third type is the stress C_2H_4 which is produced in parts per million upon exposing fruits to stress conditions (Yang and Hottman, 1984). Second and third types of C2H4production are me most limiting types to cucurbits and other norticultural crops stolability (Yang, 1980 and Yang and Hoffman, 1984). The optimum temperature for C_2H_4 production by the fruits is 20-21C. Reducing or increasing the temperature beyond this range innibits its synthesis (Atta-Aly, 1992).

The impact of C_2H_4 on harvested cucurbits is deleterions except for ripening (Cantwell, 1996 and Suslow *et al.*,1997). Inhibiting its biosynthesis and/or action can arrest the deleterious impacts of C_2H_4 on cucurbits. This can be achieved by cold but not chilling storage and by using MA, CA and LPS techniques (Kader, 1992). Also aminoethoxyvenyiglycine and/or aminooxyacetic acid can be used as anti-C_2H_4 biosyntnesis agents (Yang, 1980).

2.2.3. Transpiration and water loss

Water loss is a main cause of deterioration because it results not only in direct quantitative losses (loss of weight), but also in qualitative losses such as losses in appearance (shriveling), textural and nutritional quality. Transpiration and water loss is influenced by internal or commodity factors (morphological and anatomical characteristics, surface-to-volume ratio, surface injuries and maturity stage) and external or environmental factors (temperature, RH, air movement and atmospheric pressure inside the storage facility). Transpiration is a physical process that can be controlled by product waxing (Kader, 1992) and other surface coating and wrapping or by manipulating the environment such as maintenance of high RH and control of air circulation (Kasmire, 1978).

2.2.4. Physiological disorders

Reducing or increasing storage temperature beyond the biological temperature limits (below O^{o}C or above 40^{o}C) will directly alter plant and fruit cell metabolism to limits causing freezing or heat injury, respectively. Cucurbits are also chilling sensitive meaning that they will be physiologically injured if kept at low temperature above O^{o}C. This kind of injury is called enilling injury (Cl) and is determined by cucurbit variety, magnitude of temperature reduction and chilling exposing duration (Kader, 1992 and Morris, 1982). Each of these physiological disorders will be separately discussed.

2.2.4.1. Heat injury: Most of cucurbits heat injuries are developed as a result of improper field conditions before, at and after harvest and rarely to postharvest temperature storage if managed. Direct exposure to sunlight or excessive high temperature is the main reason behind cucurbits heat injury development (Kader, 1992 and Kasmire,1978). The magnitude of heat injury markedly increased when fruits are left in the field under direct sunlight for several hours, particularly in the mid-day time. Symptoms of heat injury are bleaching, surface burning or scalding, uneven ripening, excessive softening and desiccation. Placing harvested cucurbits, immediately after harvest, in a shaded place in the farm followed by fast cooling and direct holding at crop desirable temperature will completely arrest cucurbits heat injury (Kader, 1992).

2.2.4.2. Freezing injury: Since cucurbits are sensitive to Cl, it is advised, therefore, to store them at terpperatures higher than O°C. Poor temperature management during storage, particularly for those stored close to O°C such as cantaloupe (2.5-5°C) will freeze after storage (Kader, 1992). Storing such crops at their desirable temperature will develop no freezing injury.

2.2.4.3. Chilling injury (Cl): Holding cucurbits at temperatures below their threshold temperature for a few days markedly induced fruit Cl. The threshold temperature is the temperature that is advised not to store commodity below it, otherwise Cl symptoms will be developed and visually noticed shortly after cold storage termination (Minorsky, 1985 and Morris, 1982 and Teltel *et al.*, 1989 and Wang, 1993). Such threshold temperature (Table 4) varies among all cucurbits species, varieties or even cultivars (Kader, 1992). The major symptoms of Cl include surface lesions, pitting, large sunken areas, discoloration and fast loss of chlorophyll, flavor and taste that are more common in immature-consumed cucurbits. In ripe-consumed cucurbits, however, water soaking of the internal tissues, internal discolouration (browning) of pulp and vascular strands, break down of tissues, failure of fruit ripening and senescence acceleration are the most common symptoms. These symptoms lead to increased susceptibility to decay with shortening fruit storage and shelf-life (Morris, 1982).

Table 4. The threshold temperature (minimum safe storing temperature) recommended for cucurbits storage or shipping without CI symptoms development.

Cucurbit crop	Threshold temp. (°C)	Cucurbit crop	Threshold temp. (°C)
Cucumber	7	Crenshaw	7-10
Summer squash	5	Persian	7-10
Cantaloupe) X	2-5	Watermelon	4-5
Honeydew	7-10	Winter squashes	10
Casaba	7-10	Pumpkins	10

XAmerican cantaloupe. Summarized from: Hardenburg *et al.*, (1986)

There are several hypotheses to clarify the physiological reasons behind cucurbits CS. Sharp drop in the respiration that exists in the (JS fruits as compared to the slow reduction in the non-sensitive ones. The rate of oxidation relative to glycolysis that may lead to tne accumulation of intermediate respiratory substance(s) to toxic levels (Minorsky, 1985). Tne lack of available ATP due to respiration fast drop or to membrane change in molecular ordering of membrane lipids is also proposed (Wang, 1993) which consequently alters ATPs-dependent enzymes causing substrate accumulation to the toxic levels. Minorsky (1985) also suggested that membrane dysfunction, leakage and Cazi compartmentation in relation to the cytoplasmic streaming are other factors causing metabolites irregular translocation and consequently accumulation to the toxic levels causing Cl.

Based on the previously mentioned hypotheses, cucurbits sensitivity to Cl may be due to certain physiological roles of certain cell compartments or activities. As a result, several postnarvest techniques or treatments can be used to reduce cucurbits sensitivity to Cl. These techniques or treatments include MA, CA, LPS techniques, fruit waxing or wrapping and pre-storage heat or Ca treatment. A short period of anaerobic exposure, re-warming while cold storage ana fruit ripening enhancement are effective treatments for reducing cucurbits CS. Two or more of the above mentioned techniques or treatments can be combined together for more CS reduction.

Conclusion

Cucurbits are good examples of vegetables consumed for their fruits since their fruit species differ in their stage of consumption. Based on me species, cucurbits are harvested at immature, mature or at full-ripe stage. To suite consumer preference and to arrest deteriorating factors at and after harvest, proper selection of the cultivar grown with harvesting at the most suitable stage is essential. Reducing fruit mechanical injury with fast cooling and good sanitation are effective in prolonging cucurbits storage and marketing lives. Using MA, CA, LPS techniques and supplementary treatments used for inhibiting C_2H_4 production and action and for Ci avoidance are also key factors for improving cucurbits storability without quality loss.

References

Aharoni, Y.; Copel, A. and Fallik, E.1993. Storing Galia melons in a controlled atmosphere with ethylene absorbent. HortScience, 28:725-726.

Atta-Aly, M.A.1992. Effect of high temperature on ethylene biosynthesis by tomato fruit. Postharvest Biol. Techn.,2:19-24.

Atta-Aly, M.A.; Riad, G.S.;EI-S.Lacheene, Z. and El-Beltagy, A.S.1999. Early application of ethrel extends tomato fruit cell division and increases fruit size and yield with ripening delay. J. Plant Growth Regul,18:15-24.

Barkal-Golan, P. and Phillips, D.J.1991. Postharvest heat treatment of fresh fruits and vegetables for decay control. Plant Dis.,75:1085-1089.

Cantwell, M. 1996. Honeydew and smooth-skinned melons. Perishable Handling Newsletter, Agric. Ext. Ser., Univ. Calif., Issue No. 85, Feb. 1996, pp., 10-18.

Carlson, S. 1991. Fundamentals of water disinfection. J. Water SRT-Aqua, 40: 346-356.

Clark, C. J.; Hockings, P. D.; Joyce, D. C. and Mazucco, R. A.1997. Application of magnetic resonance imaging to pre and postharvest studies of fruits and vegetables. Postharvest Biol. Techn., 11: 1-12.

Corey, K.A. and Schlimme, D.V.1988. Relationship or rind gloss and grounds spot colour to flesh quality of watermelon fruits during maturation. Scientia Horticulturae, 34: 211-218.

Eaks, I.L.1985. Effect of calcium on ripening, respiratory rate, ethylene production, and quality of avocado fruit. J. Amer. Soc. Hort. Sci., 110:145-148.

Elkashif, M.E.; Huber, D.J. and Brecht, J.K.1989. Respiration and ethylene production in harvested watermelon fruit: Evidence for nonclimacteric respiratory behavior. J. Amer. Soc. Hort. Sci., 114:81-85.

Ells, J.E. and McSay, A.E.1981. Yield comparisons of pickling cucumber cultivar trials for one-over harvesting. HortScience, 16:187-189.

Hardenburg, R.E.; Watada, A.E. and Wang, C.Y.1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks.U.S. Dept. Agr. Res. Ser., Agr. Hb. No. 66, P. 1-28&50-70.

Kader, A.A.1983. Postharvest quality maintenance of fruits and vegetables in developing countries. In M. Lieberman (Ed.). Postharvest Physiology and Crop Preservation. Plenum Pub. Co., 1983, P. 455-469.

Kader, A.A.1985. Ethylene-induced senescence and physiological disorders in harvested horticultural crops, HortScience, 20: 54-57.

Kader, A.A.1992. Postharvest biology and technology. An overview. In A. Kader (Ed.). Postharvest Technology of Horticultural Crops. 2nd ed. Univ. Calif., Div. Agr. & Natl. Res. Pub. 3311, P. 15-20.

Kanellis, A.K.; Morris, L.L. and Saltveit, M. E.1986. Effect of stage of development on postharvest behavior of cucumber fruit. HortScience, 21:1165-1167.

Kasmire, R.F. 1978. Responses of horticultural crops to atmospheric composition Perishables Handling Newsletter, Agr. Ext. Ser., Univ. Calif., Issue No. 40, June 1978, P. 1-3 & 9-11.

Kasmire, R.F. and Ahrens, M.J.1992. Handling of horticultural crops at destination Markets. In A. Kader (Ed.). Postharvest Technology of Horticultural Crops 2nd ed., Univ. Calif., Div. Agr. & Natl. Res. Pulb. 3311, P.167-180.

Lester, G.1995. Regulation of muskmelon fruit senescence by calcium. Acta Horticulturae 398:41-42.

Lester, G.; Dunlap, J. and Lingle, S.1988. Effect of postharvest heating on electrolyte leakage and fresh weight loss from stored muskmelon fruit. HortScience, 23: 407.

McCollum, T.G.; Huber, D.J. and Cantliffe, D.J.1988. Soluble sugar accumulation and activity of related enzymes during muskmelon fruit development. J. Amer. Soc. Hort. Sci., 113:399-403.

McCollum, T.G. and McDonald, R.E.1993. Tolerance of cucumber fruit to immersion in heated water and subsequent effects on chilling tolerance. Acta Horticulturae, 343:233-237.

Miccolis, V. and Saltveit, M.E.1991. Morphological and physiological changes during fruit growth and maturation of seven melon cultivars. J. Amer. Soc. Hort.Sci., 116:1025-1029.

Minorsky, P.V.1985. An heuristic hypothesis of chilling injury in plants: a role for calcium as primary physiological transducer of injury. Plant, Cell and Environment, 8:75-94.

Morris, L.L.1982. Chilling injury of horticultural crops: An overview. Hort. Science, 17:161-162.

Nonnecke, I.L.1989. *Vegetable Production*. AVI Pub. Van Nostrand Reinhold, New York. P. 505-569.

Poovaiah, B.W.1985. Role of calcium in prolonging life of fruits and vegetables. Food Technology, May 1986, P. 86-89.

Risse, L.A. and Hatton, T.T.1982. Sensitivity of watermelon to ethylene during storage. HortScience, 17:946-948.

Salunkhe, D.K. and Desai, B.B.1984. Postharvest Biotechnology of Vegetables. No. II. CRC Press, Inc., Boca Raton. Florida, P. 63-83.

Suslow, T.V.; Cantwell, M. and Mitchell, J.1997. Honeydew melon, recommendation for maintaining postharvest quality. Perishable Handling Newsletter. Agr. Ext. Ser., Univ. Calif., Issue No. 89, Feb. 997, P. 19-22.

Teltel, D.C.; Aharoni, Y. and Barkal-Golan, R.1989. The use of heat treatments to extent the shelf life of Galia melons. J. Hort. Sci., 64:367-372.

Wang, C.Y.1993. Relation of chilling stress to polyamines in zucchini squash. Acta Horticulturae, 343:288-289.

Wang, C.Y.1994. Combined treatment of heat shock and low temperature conditioning reduces shilling injury in zucchini squash. Postharvest Biol. Techn., 4: 65-73.

Wei, C.I.; Huang, T.S.; Kim, J.M.; Lin, W.F.; Tamplin, M.L. and Bartz, J.A.1995. Growth and survival of Salmonella montevideo on tomatoes and disinfection with chlorinated water. J. Food Protection, 58: 829-836.

Yang, S.F.1980. Regulation of ethylene biosynthesis. HortScience 15: 238-243.

Yang, S.F. and Hoffman, N.S. 1984. Ethylene biosynthesis and its regulation in higher plants. Annu. Rev. Plant Physiol. 35: 155-189.

عوامل التدهور أثناء وبعد الحصاد لثمار المحاصيل القرعية وتقنيات تفاديها

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الخلاصة

إنَّ تقنية تقليل سرعة تدهور المحاصيل القرعية بعد حصادها مع زيادة قابليتها للتخزين والحفاظ على جودتها تبدأ من الحقل وذلك بضرورة اختيار أفضل الأصناف البستانية عند الزراعة على أن يتم الحصاد عند وصول المحصول إلى أنسب مرحلة للحصاد اعتماداً على ذوق المستهلك المستهدف ومسافة وزمن الشحن بعد الحصاد. يُراعى أيضاً، عند الحصاد وأثناء التداول، تقليل تعريض الثمار للأضرار الميكانيكية لأقل حد ممكن مع إجراء معاملات تطهير المحصول بعد الحصاد باستخدام المواد المناسبة والمسموح بها دولياً. بعد الحصاد مباشرة، يتم تبريد المحصول مبدئياً مع اختيار وسيلة التبريد المبدئي المثلى والمناسبة لصنف المحصول ومنطقة الإنتاج. يعقب ذلك مباشرةً حفظ المحصول مبرداً وعلى درجة الحرارة المثلى له والتي تتباين بتباين نوع وصنف المحصول ومرحلة حصاده حتى القيام بعملية الشحن أو الخزين. يراعى أيضاً ضرورة مراقبة ومتابعة ضبط درجة حرارة ورطوبة الشاحنة أو المخزن التي تناسب نوعية المحصول مع التهوية الدائمة حتى يمكن الحفاظ على جودة المحصول لأطول فترة ممكنة. وعند الشحن أو التخزين يجب عدم خلط ثمار المحاصيل القرعية المنتجة للإيثيلين مثل الكنتالوب وشهد العسل مع ثمار المحاصيل الأخرى الحساسة له مثل الخيار والكوسة والبطيخ ويمكن أيضاً استخدام تقنيات التخلص من الإيثيلين أو أكسدته أو تثبيط تخليقه أو فعله أثناء الشحن أو التخزين خاصة لثمار القرعيات التي تؤكل غضة وذلك لتلافي أضراره والتي تؤدي إلى سرعة تدهور المحصول بعد حصاده واندفاعه للشيخوخة.

ومن المعروف أنَّ ثمار المحاصيل القرعية من الثمار الحساسة للإصابة بأضرار البرودة عند تخزينها أو شحنها على درجة حرارة منخفضة ولكن أعلى من درجة الصفر المئوي. ولكل محصول من محاصيل العائلة القرعية درجة حرارة حدية لا يُنصح بتخزينه أو شحنه على درجة حرارة أقل منها حتى لا يُصاب بأضرار البرودة برغم أنها أعلى من الصفر المئوي. ولهذا يُنصح بتخزين ثمار المحاصيل القرعية تخزيناً مبرداً على درجة الحرارة الحدية التي تناسبه أو على درجة حرارة أقل منها قليلاً حتى لاتصاب الثمار بأضرار البرودة والتي لاتظهر أعراضها إلا بعد التخزين المبرد وأثناء العرض في السوق مسببة تدهوراً حاداً في جودة المحصول وبالتالي عدم تسويقه. ولتقليل حساسية ثمار القرعيات للإصابة بأضرار البرودة يجب إجراء معاملة أو أكثر من معاملات تقليل حساسية الثمار للبرودة والتي بإجرائها يمكن تخزين المحصول مبرداً دون إصابته بأضرار البرودة. ومن هذه المعاملات تهيئة الثمار بمعاملات خاصة أو إجراء المعاملات الحرارية أو تعريض الثمار لظروف لاهوائية لفترةٍ وجيزة أو غمس الثمار في محلول مخفف من الكالسيوم قبل التخزين أو الشحن المبرد. أيضاً تعتبر المعاملة بالإيثيلين للقرعيات التي تؤكل ناضجة قبل تخزينها أو إعادة تدفئتها، أثناء التخزين أو الشحن المبرد، من المعاملات التي تقلل بشدة من حساسية الثمار للإصابة بأضرار البرودة. يمكن أيضاً استخدام تقنيات التخزين أو الشحن تحت ظروف الجو الهوائي المعدل أو المتحكم فيه أو التخزين تحت التفريغ الجزئي كوسائل أخرى يمكن استخدامها ليس فقط لتقليل حساسية ثمار المحاصيل القرعية للإصابة بأضرار البرودة ولكن أيضاً لزيادة مقدرتها التخزينية والحفاظ على جودتها لأطول فترة ممكنة.

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