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Central Valley POSTHARVEST newsletter

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OPTIMUM TEMPERATURE CONDITIONS FOR PRODUCE HANDLERS

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Immediately after harvest, fruits and vegetables begin to senesce, deteriorate and postharvest losses occur. As part of the fruit senescent process, fruits and vegetables start to lose weight, firmness, flavor, and become more susceptible to decay and physiological problems. It has been accepted that postharvest losses, depending on the commodity, reached approximately 5-25% in developed countries and 20-50% in developing countries. A recent survey carried out in the UK claims that an estimated 4.4 million apples are tossed every day along with 5.5 million potatoes, 2.8 million tomatoes, 1.6 million bananas and 1.2 million oranges due to deterioration problems. Based on those estimates, the five items alone add up to 525,000 tons of food waste a year. www.lovefoodhatewaste.com.

The U.S. Department of Agriculture's Economic Research Service estimates 57% of the weight of fresh fruits and 51% of the weight of fresh vegetables in 2005 were not consumed.

In India, where turnover is faster than in the UK and USA, according to a recent article in the Hindustan Times, up to 30% of food produced in India is wasted because of poor postharvest handling.

The rate of losses is mainly related to temperature, time of this temperature exposure and commodity genetic make up. Temperature controls the biological processes associated with fruit and vegetable deterioration, but the relationship between temperature and rate of deterioration is not linear. Thus, rate of deterioration is 3-, 7.5-, 15-, and 22-fold faster at 10, 20, 30, and 40°C than at 0°C (Table 1). These differences in deterioration rate at different temperatures are important to consider during postharvest handling management. Environmental conditions such as high temperature, atmosphere environment, air velocity, relative humidity, vapor pressure deficit, ethylene, light and other factors surrounding commodities will affect fruit deterioration mainly by accelerating the biological processes.

Temperature is the most important environmental factor controlling deterioration among these environmental conditions. Temperature also has a direct effect on fruit deterioration by inducing heat damage, chilling and freezing damage. Thus, the use of the right temperature during postharvest handling from production to consumption is the most powerful postharvest tool that we have to maintain quality and reduce losses. In some special circumstances when ideal temperature cannot be achieved, it is recommended to stay near the optimum but away from exposure to undesirable temperatures. In general, postharvest losses are higher at high temperatures compared to low temperatures. However, fruits and vegetables can be rapidly destroyed if they are stored at the wrong low temperature. The ideal storage temperature varies among commodities, between cultivars within one species or even the same cultivar depending on their postharvest life. Commodity damage due to freezing, chilling injury or heat injury damage occurred at different temperatures depending on the specific cultivar. Therefore, knowledge of the specific optimum temperature requirement for each commodity is the essential key for a successful postharvest handling operation.

Most commodities are shipped from the point of production to regional, overseas, or local distributors, such as terminal markets, independent wholesalers or chain store distribution centers. Produce orders are assembled at these sites and then shipped to retail stores, restaurants, or institutions such as schools or hospitals. Produce and floral items lose quality during these marketing steps. The amount of quality loss accumulates at each step.

The consumer will receive good quality produce only if each operation in the handling chain minimizes abuse caused by mechanical damage, improper temperature and RH, moisture loss, ethylene damage, odor contamination, and excessive storage time. Therefore, it is important that fruit handlers receive commodities that have been handled under the ideal temperature and protect them during delivery to consumers.

Freezing Injury

When tissue is frozen, the exchange of metabolites between several compartments within the cells is negatively affected. Water in the intercellular spaces freezes and total cell dehydration occurs. In addition, physical freezing damage injury occurs when ice crystals form in the tissues as water volume increases when changed from liquid to frozen. As a general rule, approximately 1°C (2°F) above the highest temperature at which freezing of a specific commodity may occur should be recommended as the optimum storage temperature. Freezing injury can be encountered in fruits and/or vegetables that are purposely stored at near their freezing point or some accidental exposure to subfreezing temperatures because of some malfunction in the refrigeration system and/or air distribution. Occasionally freezing can occur in any type of fruit, but in all cases decay development occurs faster on freeze injured fruit. Freezing injury can occur whenever fruit are exposed to too low temperatures whether during cooling, storage, transport or in distribution centers. In general, a fruit freezes because of prolonged exposure to a temperature just below its freezing point; the injury pattern should relate to the pattern of soluble solids content (SSC) of the fruit. This is because low SSC fruit will freeze at a higher temperature than high SSC fruit. A relationship has been established between SSC and the freezing point for stone fruit (Table 2). For this reason, to safely utilize temperatures near the freezing point, one must know the SSC variability within fruits.

The most common symptom of freezing injury is a water soaked appearance; tissues injured by freezing generally lose rigidity and become mushy upon thawing. Freezing injury will appear as glassy, “water soaked” or translucent areas in the flesh. With time these injured areas will dry leaving open “gas pockets” in the flesh. The freeze injured tissue of most fruits will begin to brown as a result of enzymatic oxidation of phenols released by the injured tissue. When freezing occurs at the fruit surface, the glossy or browning symptoms may be visible without cutting. Often when injury is seen it is necessary to determine whether it is indeed from freezing or whether it is from some other cause. Similar symptoms can be associated with injury from other causes. Water core in apples and some senescent breakdown problems can cause flesh translucency. Many disorders can cause internal tissue browning or even the development of gas pockets. Surface browning may be confused with scald disorders in apples, Asian and European pears, or even chemical or mechanical injuries on many fruits. Freezing injury can occur internally before external symptoms become visible as in the case of ‘Bartlett’ pears in which core tissues have lower soluble solids content and freeze before outer flesh tissues. For pears and apples that we have evaluated, the lowest SSC is in the core area, and the highest SSC in the outer flesh near the blossom end of the fruit. For kiwifruit, the lowest SSC is in the flesh nearest the stem end, the highest SSC is in the core and flesh tissue near the blossom end. While we would expect to see freezing injury appear first in the core area of a pear, for example, we should verify the relationship between SSC and injury with refractometer measurements. If damage is caused during cold storage, freezing will occur on the most exposed fruit, i.e. near box openings located on the sides and corners of the pallet. If damage occurred during transportation (truck or marine containers) freezing damage will be related to cold air distribution within these vessels; for example, if cold air is bottom or top delivered or if a short cycle occurred in that container. Damage may be worse on the exposed surface of the fruit, and there will be no relationship between freezing injury and the soluble solids content (SSC) patterns within or among fruits. Freezing injury should thus be seen first in the lowest SSC portions of the fruit and in the lowest SSC fruit within a lot. Fresh fruits and vegetables react to freezing damage in different ways. Some of them may be frozen and thawed a number of times with little or no damage symptoms. Others are permanently injured by even a slight freezing. Thus, the time that a commodity is exposed below its freezing point is also an important factor in freezing injury expression. For example, both tomatoes and parsnips have freezing points of -1.1 to -0.6°C (30 to 31°F), but parsnips can be frozen and thawed several times without apparent injury, whereas tomatoes are ruined after only one freezing.

Freezing injury can be avoided during the postharvest handling period by maintaining temperatures just above freezing which requires good equipment, careful management and reliable knowledge. Of equal importance is accurate monitoring of soluble solids content (SSC) of fruit as a basis for estimating the freezing point of the tissue.

Chilling Injury

Many fruits, vegetables and ornamentals of tropical or subtropical origin are sensitive to low temperature injury. Chilling injury occurs when commodities of tropical and subtropical origin, such as poinsettia, bananas and tomatoes, are held at temperatures above their freezing points. In these cases, there is no ice formation internally, but some chemical changes in their tissue chemical composition, especially lipids-membrane changes, lead to chilling injury damage. These commodities are injured after a period of exposure to chilling temperatures below 10 to 15°C (50 to 59°F) but well above their freezing points. A few temperate-zone commodities or cultivars within a given commodity may be susceptible to chilling injury (Table 3). For example, internal breakdown of some peaches, plums and nectarines occurs below 10°C (50°F) and maximizes at about 5°C (41°F). Those temperate crops, in general, have lower threshold temperatures, < 5°C (41°F). In most cases, chilling injury is manifested in a variety of symptoms, such as surface pitting, surface lesions, discoloration (external and/or internal), appearance of water-soaked areas, development of necrotic areas, failure of mature fruits to ripen, increased susceptibility to decay, shorter storage life, cessation of growth, loss of sprouting ability of propagules, and loss of characteristic flavor and aroma (Table 4). Many physiological and biochemical changes occur before chilling injury symptoms such as cessation of protoplasmic streaming, changes in membrane permeability, disorganization of protoplasm, loss of mitochondrial activity, and alteration of respiratory metabolism ending in cellular dysfunctions. At these chilling temperatures, the tissues weaken because they are unable to carry on normal metabolic processes. When chilling stress is prolonged, these cell alterations will lead to the development of these chilling injury symptoms. Temperature and duration of exposure are involved in the development of chilling injury. Damage may occur in a short time if temperatures are considerably below the threshold level, but a product may be able to withstand temperatures a few degrees in the critical zone for a longer time before injury becomes irreversible. Maturity at harvest and degree of ripeness are important factors in determining chilling sensitivity in some fruits like avocados, honeydew melons, and tomatoes. The effects of chilling are cumulative in some commodities. Low temperatures in transit, or even in the field shortly before harvest, add to the total effects of chilling that occur in cold storage. In some cases, products that are chilled will still look sound when remaining in low temperatures. However, symptoms of chilling injury become evident in a short time after they are removed to warmer temperatures. Several treatments which have been shown to alleviate chilling injury include: intermittent warming; high or low temperature preconditioning; calcium, chloride dips: CA or MAP storage; pretreatments with ethylene, abscisic acid, methyl jasmonate and other natural compounds.

Heat Injury

Commodity losses caused by high temperature exposure can occur before and after harvest. High temperature near harvest can sunburn areas on persimmons that turn into black spots after harvest or around the pit in apricot and some plums (pit burn). When produce is held above 35°C, metabolism becomes abnormal and results in a breakdown of membrane integrity. Peel of some Cavendish banana cultivars remains green and red pigment (lycopene) accumulation in tomatoes is inhibited. In some cases tissues also developed a watery or translucent appearance that is called “boiled”. In plum it has been observed that high temperature during “off the tree ripening” or long delayed cooling induce “off flavor” on ripe fruit.

Optimum Temperature for Long Term Storage or Shipment

The recommended storage temperatures for commodities that are not susceptible to chilling injury are as low as possible but slightly above their freezing point. Commodity storage temperatures should be kept 1°C (2°F) above their highest freezing point. Certainly, this will depend on your ability to control temperature in your storage facilities and other factors. If temperatures drop below the optimum range for a given commodity, freezing injury may result while elevated temperatures will shorten storage life. The recommended ideal storage temperatures and other environmental conditions for many horticultural products can be found in USDA Agricultural Handbook 66 or on the UC Davis Postharvest Technology website at http://postharvest.ucdavis.edu.

In addition to the ideal storage temperature, delay of cooling is also an important issue in the development of temperature management policies for your postharvest fruit handling operations. The lapse of time between harvest and fruit cooling (delayed cooling) has a very important effect on fruit quality, storage, and market performance. In general, an uncontrolled delay in cooling increases the rates of fruit softening and ripening, CO_2 and ethylene production, water loss, and the onset and severity of physiological disorders and decay. In some specific cases, there are some benefits in packing warm fruit and then using a controlled delayed cooling. One of these is a reduction in the incidence of bruising – which is one of the main causes of fruit losses in stone fruit – cherries, peaches, plums, and nectarines. Controlled delayed cooling or warming is a tool that is being successfully used to delay chilling symptom expression in several commodities. Thus, an understanding of the relationship between cooling delay sensitivity, fruit bruising, and temperature can be used to decrease bruising incidence without significantly increasing postharvest deterioration. Unfortunately, the effects of cooling delays on deterioration often differ from species to species, sometimes between varieties, and may even vary depending upon the physiological maturity of the individual fruit. Thus, specific information for each variety needs to be made available in order to develop an optimum temperature management program for your packing operation and assure that fruit of high quality reaches the consumers.

Temperature Requirement at the Wholesale Distribution Center Storage (Less than a Week)

Products should be received at their proper long-term storage temperature and then stored at that temperature. Because of lack of facility space or capacity to satisfy ideal commodity storage environmental requirements and because of their fast turn around under these conditions, commodities can be grouped under three categories (Table 5). The RH of the storage atmosphere should be 90-98%, especially for green vegetables. Fruit when stored at low temperatures can be stored short term at 85 to 95% RH. The lowest temperature range of 0 to 2°C (32 to 35.6°F) should be used for the majority of the green, non-fruit vegetables and temperate fruits and melons. If there is enough capacity in the facility, the fruits should be stored separately from the vegetables. This allows installing equipment to maintain higher RH (90 to 98%) for the vegetables as many of them are quite susceptible to water loss and wilting. Cut flowers and nursery items are also grouped into these recommended three categories. If handled with produce, the floral items in group No. 1 should be in the 1A vegetable room to minimize exposure to ethylene produced by many fruits (Table 6). The two warmer temperature ranges are used for chilling-sensitive produce (Groups 2 and 3). The highest temperature room can also be used to ripen fruits that only require a warm environment to ripen. If refrigerated space is limited, low temperature fruits, vegetables and flowers can be mixed in a room; air-conditioned space at 20 to 25°C (68 to 77°F) can be used for highest temperature products (Group 3).

Many green vegetables and most floral products are quite sensitive to ethylene damage. Tips to keep ethylene away from these products are discussed in the Ethylene section.

Large wholesale distribution facilities, whether independently owned or integrated with a retail chain, strive to receive only the amount of produce that can be shipped the following day. A few fruits such as mature-green avocados, bananas, mangos, and tomatoes are ripened before shipment to retail stores and may be held in special ripening rooms for several days.

Temperature Requirement for the Back Room

Fresh produce received at the grocery store is kept in storage rooms and/or display areas (in cabinets/cases or on racks/tables) for a few hours to a few days before purchased by consumers or removed by produce personnel. During this short time, the key factors in maintaining quality are careful handling to minimize mechanical injuries, storage and display within optimum ranges of temperature and RH, and proper sanitation of storage and display areas. Expedited handling and effective rotation (first in, first out) of the produce is also recommended.

<u>Storage back room</u>: The number and size of storage rooms depend upon store size and frequency of produce delivery to the grocery store. If three rooms are available for produce, they are best designated for short-term storage of the three groups of fruits and vegetables, i.e. No. 1 at 0 to 2°C (32 to 35.6°F), No. 2 at 7 to 10°C (44.6 to 50°F), and No. 3 at 13 to 18°C (55.4 to 64.4°F). If only two rooms are available, one should be used for group No. 1 at 0 to 2°C (32 to 35.6°F) and the other for groups No. 2 and No. 3 (with a compromise temperature range of 10 to 14°C (50 to 57.2°F). If only one room is available, it should be kept at a compromise temperature of 5°C (41°F) and used for groups No. 1 and No. 2. while group No. 3 should be kept in an air conditioned area. Cut flowers and other ornamentals that are best kept at 0 to 2°C (32 to 35.6°F) can be combined with group No. 1 fruits and vegetables since ethylene production and action at this temperature range are minimal. Ornamentals that are chilling-sensitive and ethylene-sensitive should be handled in a separate area from the ethylene-producing fruits of group No. 3 to avoid ethylene damage. All produce items should be near their optimum storage temperature when received at the grocery store and should be unloaded and moved quickly to their appropriate storage area. Keeping cold commodities at warmer temperatures for more than a few minutes can result in water condensation on the commodity, which may encourage the growth of decay producing pathogens. RH should be kept within the optimum range of 85 to 95% for most commodities to minimize water loss. Good air circulation within the storage room is essential to maintain proper product temperature and RH. Thus, space for air movement should be kept around stacks or pallets of boxes and between them and the room walls. Enough fresh, ethylene-free air should be introduced into storage rooms to keep ethylene < 1 ppm, and preferably < 0.1 ppm if it can be done economically using fresh air exchanges and/or ethylene scrubbing systems.

Temperature Requirements for the Retail Display

Most produce items in groups No. 1 and No. 2 should be displayed in refrigerated display cases. Display at store ambient air temperature is acceptable for some commodities, including produce that does not lose water quickly and has a long shelf-life like apple, pear, kiwifruit, and orange. Produce that is on sale (special promotion) or will be on display for a few hours (like grapes and strawberries) can also be stored at ambient temperatures. Ideally, the display case temperature range should match the recommended range for each group of commodities, i.e., 0 to 2°C (32 to 35.6°F) for group No. 1 including all fresh-cut products and 7 to 10°C (44.6 to 50°F) for group No. 2. Since display cases usually do not have the refrigeration capacity to cool the products, it is important to assure that the product is near its recommended temperature when it is placed in the display case. The produce should not obstruct the discharge air and return air outlets to maintain good cold air circulation within the case. Also, produce should not be stacked so densely that cold air circulation is blocked or so high that it is out of the refrigerated zone and becomes exposed to ambient air temperatures. Refrigerated display cases have a horizontal or vertical air flow system and either a single-tier or multi-tier display shelves. They should be equipped with easy to read, accurate thermometers, which should be calibrated and monitored regularly. Performance of refrigerated display cases is influenced primarily by their refrigeration capacity, defrost options, and air circulation system. Important secondary factors include temperature, RH, and movement of surrounding air and radiant heat from the lighting sources.

A 1989 survey of temperatures of fresh-cut salads kept in refrigerated display cases in a representative sample of grocery stores indicated an overall mean temperature of about 9°C (48.2°F) with more than 78% having temperatures above about 7°C (44.6°F) and more than 17.5% having temperatures above about 13°C (55.4°F) (R.W. Daniels, Audits International). A more recent survey of temperatures of fresh-cut vegetable products kept in refrigerated display cases in some grocery stores indicates an overall mean of about 5°C (41°F) with more than 40% of the products having temperatures above about 7°C (44.6°F) (Jeff Leshuk, Sensitech, Inc.). This indicates significant improvements in maintaining the cold chain within the grocery stores, but more improvements are needed to bring the temperature range for fresh-cut products close to the recommended 0 to 2°C (32 to 35.6°F). Water loss reduction can be achieved by protecting the produce from excessive air movement, packaging in perforated polymeric films (as moisture barriers), periodic addition of sanitized, clean water by misting, and/or display on crushed ice (only useful for products that tolerate direct contact with ice). If ice is used, proper drainage of the melt water should be provided. It should be remembered that ice is not an effective way to keep the product cold unless it is well surrounded by the ice.

Non-refrigerated display tables or racks are used for most group No. 3 fruits and vegetables, which should be displayed separately. Some of the fruits in groups No. 1 and 2 may be displayed on non-refrigerated display tables or racks at ambient produce department temperatures to enhance their ripening (such as avocado, kiwifruit, and pear). Daylight simulating fluorescent bulbs are good to provide adequate lighting without heat in the produce department.

During handling at the grocery store, all precautions should be taken to minimize potential chemical or microbial contamination to maintain safety of produce. All display tables, cases, cabinets, and other fixtures must be cleaned and sanitized regularly. Unmarketable produce should be collected separate from the other waste products and used for composting.

Limited amounts of horticultural crops are sold directly to the consumer through farmers' markets or local roadside stands. These markets are usually close to the point of production and offer the consumer a product that is picked just before the time of sale. The short time between picking and sale to the consumer can allow the product to be harvested close to optimal eating quality, but ripe produce is often susceptible to mechanical damage and losses due to high temperature abuse and moisture loss. Most of these markets do not have refrigerated storage, and even if they do, they cannot quickly cool warm product. Farmers must harvest each crop as it reaches optimal maturity or ripeness and without refrigerated storage, and they must sell it immediately or risk losing some product to decay, wilting or overmaturity. Refrigerated storage allows the farmer to temporarily store product during periods of large supply and market it later when customer demand exceeds supply. Storage is also vital for holding displayed commodity from one day to the next. Non-chilling-sensitive produce can be displayed in iced displays. Crushed or flaked ice can be purchased or produced on-site from potable water. As a rough guide, a typical display requires about 20 to 24 kg/m^2 (4 to 5 lb/ft^2) of ice each day. Ice use can be minimized by protecting the display from direct sunlight and other sources of heat or drafts, and insulating the display. Design the display so that melt water does not spill into walkways. Spread ice in a thin layer over the product to provide good contact between ice and product; otherwise ice will not effectively cool the product.

Refrigerated displays are effective but can be costly to purchase. Used equipment is less expensive. Determine the potential cost effectiveness of acquiring a refrigerated display by estimating the amount of product spoilage or weight loss that might be prevented with the use of a refrigerated display. Refrigerated displays may not be cost effective for items with a long shelf life. If neither iced nor refrigerated displays are affordable, evaporative cooling can be used to reduce product temperature and slow moisture loss. Most vegetables and many fruits can be lightly sprayed with potable water. Direct evaporation from the product surface slows water loss and cools the product. Unit evaporative coolers can also be used to cool and humidify the air around produce displays. They are most beneficial in arid climates, although they have some value even in tropical areas. Placing product in vented plastic bags slows moisture loss but does not reduce product temperature.

Home Storage

The home is the last step in handling produce. Most homes have adequate conditions for short-term storage of produce. However, many products have a limited life because of previous handling conditions and duration, and home storage conditions are rarely ideal, so most produce should be consumed within a few days of purchase. Produce from the top group should always be kept in the refrigerator. Produce from the bottom group should be stored on the counter (Table 7) because these products are damaged by refrigerator temperatures [usually 3 to 6°C (38 to 44°F)]. The middle group is fruits and fruit-type vegetables that ripen (soften and become sweeter) when held at room temperature. After they have ripened they can be stored for a few days in the refrigerator without losing taste. The bottom group is chilling-sensitive commodities that usually do not show damage until after 5 days at refrigerator temperatures followed by a day or so at room temperature. If they must be held for more than 5 days they should be placed in a cool part of the house such as a basement, or in the cooler months of the year, they can be stored in a garage if the garage does not get below chilling-damage temperatures.

The counter storage area should be away from direct sunlight to prevent produce from getting too hot. These produce items do not lose moisture rapidly, so they can be held at room temperatures for several days without shriveling. However, moisture loss can be reduced by putting produce in a vented plastic bowl or a special ripening bowl that has a plastic lid. Even putting products in a paper bag will slow moisture loss. Do not put produce in sealed plastic bags on the counter because this will slow ripening due to a depletion of O_2 and accumulation of CO_2 within the bags. Ripening in a bowl or paper bag can be speeded by placing one ripe apple with every five pieces of fruit to be ripened. The apples produce ethylene gas that speeds ripening. (Fuji or Granny Smith apples do not produce much ethylene and will not enhance ripening.)

Leafy green vegetables, carrots, and berries lose moisture quickly in the refrigerator. Put them in perforated plastic bags to retard moisture loss.

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Table 1. Effect of temperature on rate of respiration and deterioration.

Temperature °F	°C	Assumed Q_{10}	Relative velocity of deterioration or respiration	Relative shelf-life	Loss per day (%)
32	0		1.0	100	1
50	10	3.0	3.0	33	3
68	20	2.5	7.5	13	8
86	30	2.0	15.0	7	14
104	40	1.5	22.0	4	25

Adapted from Kader, 2000.

Table 2. Relationship between stone fruit soluble solids content (SSC) and the freezing point.

SSC	Safe Freezing Point	
(%)	(°F)	(°C)
8.0	30.7	-0.7
10.0	30.3	-0.9
12.0	29.7	-1.3
14.0	29.4	-1.4
16.0	28.8	-1.8
18.0	28.5	-1.9

Adapted from Mitchell, 1997.

Table 3. Classification of commodities according to their susceptibility to chilling injury.

Nonsusceptible		Susceptible	
Fruits	**Vegetables**	**Fruits**	**Vegetables**
Apple*	Artichoke	Avocado	Beans, snap
Apricot	Asparagus	Banana	Cassava
Blackberry	Beans, lima	Breadfruit	Cucumber
Blueberry	Beet	Carambola	Eggplant
Cherry	Broccoli	Cherimoya	Ginger
Currant	Brussels sprouts	Citrus	Muskmelon
Date	Cabbage	Cranberry	Okra
Fig	Carrot	Durian	Peppers
Grape	Cauliflower	Feijoa	Potato
Kiwifruit	Celery	Guava	Pumpkin
Loquat	Corn, sweet	Jackfruit	Squash
Nectarine*	Endive	Jujube	Sweet potato
Peach*	Garlic	Longan	Taro
Pear	Lettuce	Lychee	Tomato
Persimmon*	Mushrooms	Mango	Watermelon
Plum*	Onion	Mangosteen	Yam
Prune	Parsley	Olive	
Raspberry	Parsnip	Papaya	
Strawberry	Peas	Passion fruit	
	Radish	Pepino	
	Spinach	Pineapple	
	Turnip	Plantain	
		Pomegranate	
		Prickly pear	
		Rambutan	
		Sapodilla	
		Sapote	
		Tamarillo	

Note: *Some cultivars are chilling sensitive. Adapted from Kader, 2000.

Table 4. Fresh produce susceptible to chilling injury when stored at low but nonfreezing temperatures.

Commodity	Lowest Safe Temperature °C	°F	Symptoms of injury when stored between 0°C and safe temperature[1]
Apples – certain cultivars	2-3[2]	36-38	Internal browning, brown core, soggy breakdown, soft scald
Asparagus	0-2	32-36	Dull, gray-green, limp tips
Atemoya	4	39	Skin darkening, failure to ripen, pulp discoloration
Avocados	4.5-13[2]	40-55	Grayish-brown discoloration of flesh
Bael	3	38	Brown spots on skin
Bananas	11.5-13[2]	53-56	Dull color when ripened
Bean (lima)	1-4.5	34-40	Rusty brown specks, spots or areas
Bean (snap)	7[2]	45	Pitting and russeting
Breadfruit	7-12	45-53	Abnormal ripening, dull brown discoloration
Choyote	5-10	41-50	Dull brown discoloration, pitting, flesh darkening
Cranberries	2	36	Rubbery texture, red flesh
Cucumbers	7	45	Pitting, water-soaked spots, decay
Eggplants	7	45	Surface scald, alternaria rot, blackening of seeds
Ginger	7	45	Softening, tissue breakdown, decay
Guavas	4.5[2]	40	Pulp injury, decay
Grapefruit	10[2]	50	Scald, pitting, watery breakdown
Jicama	13-18	55-65	Surface decay, discoloration
Lemons	11-13[2]	52-55	Pitting, membranous staining, red blotch
Limes	7-9	45-48	Pitting, turning tan with time
Lychee	3	38	Skin browning
Mangos	10-13[2]	50-55	Grayish scald like discoloration of skin, uneven ripening
Mangosteen	4-8	39-47	Hardening and browning of the cortex
Melons			
Cantaloupe	2-5[2]	36-41	Pitting, surface decay
Honey dew	7-10	45-50	Reddish-tan discoloration, pitting, surface decay, failure to ripen
Casaba	7-10	45-50	Pitting, surface decay, failure to ripen
Crenshaw and Persian	7-10	45-50	Pitting, surface decay, failure to ripen
Okra	7	45	Discoloration, water-soaked areas, pitting, decay
Olive, fresh	7	45	Internal browning
Oranges	3[2]	38	Pitting, brown stain

Commodity	Lowest Safe Temperature °C	°F	Symptoms of injury when stored between 0°C and safe temperature[1]
Papayas	7	45	Pitting, failure to ripen, off-flavor, decay
Passion fruit	10	50	Dark red discoloration on skin, loss of flavor, decay
Peppers, sweet	7	45	Sheet pitting, alternaria rot on pods and calyxes, darkening of seeds
Pineapples	7-10[2]	45-50	Dull green when ripen, internal browning
Pomegranates	4.5	40	Pitting, external and internal browning
Potatoes	3[2]	38	Mahogany browning, sweetening
Pumpkins and hardshell squash	10	50	Decay, especially alternaria rot
Rambutan	10	50	Darkening of exocarp
Sweet potatoes	13	55	Decay, pitting, internal discoloration, hardcore when cooked
Tamarillos	3-4	37-40	Surface pitting, discoloration
Taro	10	50	Internal browning, decay
Tomatoes			
Ripe	7-10[2]	45-50	Watersoaking and softening, decay
Mature-green	13	55	Poor color when ripe, alternaria rot
Water convolvulus	10	50	Darkening of leaves and stems
Watermelons	4.5	40	Pitting, objectionable flavor

[1] Symptoms often become apparent only after removal to warm temperatures, as in marketing.
[2] See text.

Adapted from Wang, 2007.

Table 5. Compatible fresh fruits and vegetables during 7-day storage. Ethylene should be kept below 1 μL^{-1} (1 ppm) in the storage area. From Thompson et al. (1996).

	Groups No. 1A and 1B 0 – 2°C, 1A: 90 to 98% RH, 1B: 85 to 95% RH				**Group No.2 7 – 10°C with 85 to 95% RH**		**Group No. 3 13 to 18°C with 85 to 95% RH**	
Vegetables	alfalfa sprouts	Chinese cabbage*	mint*	**1A**	basil*		bitter melon	
	amaranth*	Chinese turnip	mushroom		beans; snap, green, wax		boniato*	
	anise*	collard*	mustard greens*		cactus leaves (nopales)*		cassava	
	artichoke	corn; sweet, baby	parsley*		calabaza		dry onion	
	arugula*	cut vegetables	parsnip		chayote*		ginger	
	asparagus*	daikon*	radicchio		cowpea (Southern pea)		jicama	
	beans; fava, lima	endive*-chicory	radish		cucumber*		potato	
	bean sprouts	escarole*	rutabaga		eggplant*		pumpkin	
	beet	fennel*	rhubarb		kiwano (horned melon)		squash; Winter (hard rind)*	
	Belgian endive*	garlic	salsify		long bean		sweet potato*	
	bok choy*	green onion*	scorzonera		malanga*		taro (dasheen)	
	broccoli*	herbs* (not basil)	shallot*		okra*		tomato; ripe, partially ripe	
	broccoflower*	horseradish	snow pea*		pepper; bell, chili		& mature green	
	Brussels sprouts*	Jerusalem artichoke	spinach*		squash; Summer, (soft rind)*		yam*	
	cabbage*	kailon*	sweet pea*		tomatillo			
	carrot*	kale*	Swiss chard*		winged bean			
	cauliflower*	kohlrabi	turnip					
	celeriac	leek*	turnip greens*					
	celery*	lettuce*	waterchestnut					
	chard*		watercress*					
Fruits and Melons	apple[e]	elderberry	prune*	**1B**	avocado, unripe[e]	lime*	atemoya[e]	sapodilla[e]
	apricot[e]	fig	quince*		babaco	limequat	banana[e]	sapote[e]
	avocado, ripe[e]	gooseberry	raspberry		cactus pear, tuna	mandarin	breadfruit[e]	soursop[e]
	Barbados cherry	grape	strawberry		calamondin	mango, ripe[e]	canistel[e]	watermelon
	blackberry	kiwifruit*[e]			carambola	olive	casaba melon	
	blueberry	loganberry			cranberry	orange	cherimoya[e]	
	boysenberry	longan			custard apple[e]	passion fruit	Crenshaw melon[e]	
	caimito	loquat			durian, ripe[e]	pepino	honeydew melon[e]	
	cantaloupe[e]	lychee			feijoa	pineapple	jaboticaba	
	cashew apple	nectarine			granadilla[e]	pummelo	jackfruit[e]	
	cherry	peach			grapefruit*	sugar apple	mamey[e]	
	coconut	pear (Asian & European)			guava[e]	tamarillo	mangosteen[e]	
	currant	persimmon*			Juan canary melon[e]	tamarind	papaya[e]	
	fresh-cut fruits[e]	plum, ripe*			kumquat	tangelo	Persian melon[e]	
	date	plumcot, ripe*			lemon*	tangerine	plantain[e]	
	dewberry	pomegranate				ugli fruit	rambutan	

* Sensitive to ethylene damage; [e] produce significant ethylene. Adapted from Thompson, J. et al., 1996.

Table 6. Compatible flowers, florist's foliage and nursery items during 7-day storage. (*) Can store with category 1A vegetables in a mixed produce storage. Ethylene should be kept below 1 μL^{-1} (1 ppm) in the storage area.

	Group No. 1* **0 – 2°C;** **85 to 95% RH**			**Group No. 2** **7 – 10°C;** **85 to 95% RH**	**Group No. 3** **13 – 18°C;** **85 to 95% RH**
Flowers	Acacia	Gaillardia	Protea	Anemone	African violet
	Alstroemeria	Gardenia	Ranunculus	Bird of paradise	Anthurium
	Allium	Gerbera	Rose	Camellia	Ginger
	Aster	Gladiolus	Snapdragon	Eucharis	Heliconia
	Bouvardia	Gypsophlia	Snowdrop	Gloriosa	Orchid, cattleya, vandal
	Buddleia	Heather	Squill	Godetia	Poinsettia
	Calendula	Hyacinth	Statice	Sweet-william	
	Candy tuft	Iris	Stephanotis		Bulbs, corms, rhizomes, tubers & roots
	Carnation	Laceflower	Stevia		
	Chrysanthemum	Lilac	Stock		Nursery stock
	Clarkia	Lily	Strawflower		
	Columbine	Lily-of-the-valley	Sweet pea		
	Coreopsis	Lupine	Tulip		
	Cornflower	Marigolds	Violet		
	Cosmos	Mignonette	Zinnia		
	Crocus	Narcissus			
	Dahlia	Orchid, Cymbidium	Cuttings & scions		
	Daisy, English, Marguerite, Shasta	Ornithogalum			
		Poppy			
	Delphinium	Peony			
	Feverfew	Phlox			
	Forget-me-not	Primrose			
	Foxglove				
	Freesia				
Florist's Foliage (Greens)	Adiantum (Maidenhair)	Gallax	Pittosporum	Chamaedoria	Dieffenbachia
		Ground pine	Rhododendron	Cordyline	Staghorn fern
	Asparagus (plumose)	Hedera	Salal (lemon leaf)	Palm	
		Hex (holly)	Scotch-broom	Podocarpus	
	Buxus (boxwood)	Juniper	Smilax		
	Camellia	Leatherleaf	Vaccinium (huckleberry)		
	Cedar	Leucothoe			
	Croton	Magnolia	Woodwardia fern		
	Dracaena	Mistletoe			
	Fern, dagger, wood	Mountain-laurel			
	Eucalyptus	Myrtus (myrtle)			
		Philodendron			

Adapted from Thompson, J. et al., 1996.

Table 7. Home storage of fruits and vegetables.

Storage location	Fruits and melons	Vegetables
Store in refrigerator	Apples (more than 7 days)	Artichokes
	Apricots	Asparagus
	Blackberries	Beets
	Blueberries	Belgian endive
	Cherries	Broccoli
	Cut fruits	Brussels sprouts
	Figs	Cabbage
	Grapes	Carrots
	Nashi (Asian pears)	Cauliflower
	Raspberries	Celery
	Strawberries	Cut vegetables
		Green beans
		Green onions
		Herbs (not basil)
		Leafy vegetables
		Leeks
		Lettuce
		Lima beans
		Mushrooms
		Peas
		Radishes
		Spinach
		Sprouts
		Summer squashes
		Sweet corn
Ripen on the counter first, then store in the refrigerator	Avocados	
	Kiwifruit	
	Nectarines	
	Peaches	
	Pears	
	Plums	
	Plumcots	
Store only at room Temperature	Apples (fewer than 7 days)	Basil (in water)
	Bananas	Cucumbers†
	Grapefruit	Dry onions*
	Lemons	Eggplant†
	Limes	Garlic*
	Mandarins	Ginger
	Mangoes	Jicama
	Muskmelons	Peppers†
	Oranges	Potatoes*
	Papayas	Pumpkins
	Persimmons	Sweet potatoes*
	Pineapple	Tomatoes
	Plantain	Winter squashes
	Pomegranates	
	Watermelons	

Notes:

* Store garlic, onions, potatoes, and sweet potatoes in a well-ventilated area in the pantry. Protect potatoes from light to avoid greening.

† Cucumbers, eggplant, and peppers can be kept in the refrigerator for 1 to 3 days if they are used soon after removal from the refrigerator.

Adapted from Thompson and Crisosto, 2000.

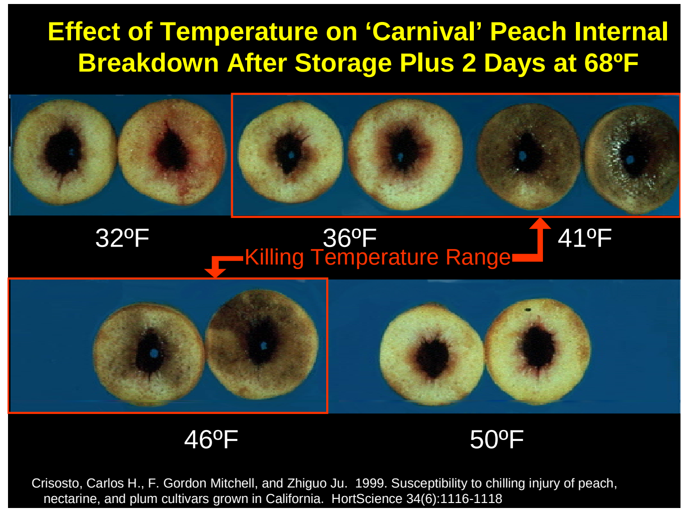
Pear freezing internal injury

Kiwifruit Freezing Damage

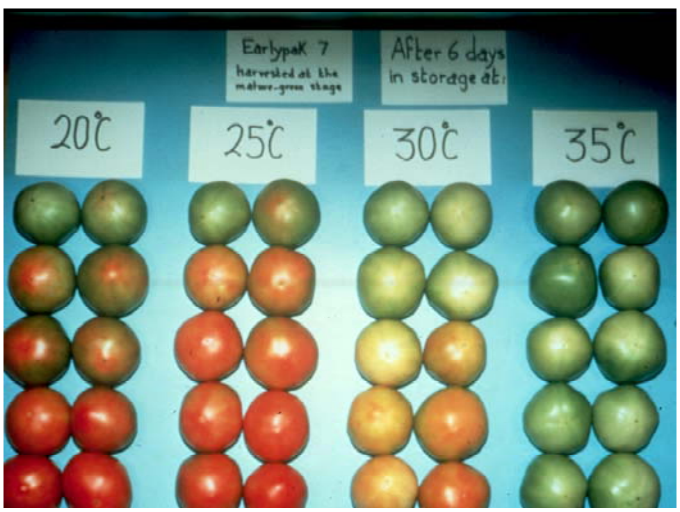
Potato Chips Chilling Injury

Banana and tomato chilling injury

Grapefruit Chilling Injury



Peach Chilling Injury



Tomato heat damage

Poinsettia chilling injury

Table grapes freezing damage

FUTURE EVENTS

Stone Fruit Environmental Stewardship Program sponsored by UC IPM and the California Tree Fruit Agreement (CTFA). Friday, November 7, 2008 – 9:30 AM to noon – at the Kearney Agricultural Center in Parlier. Planned speakers will be from entomology, plant pathology, Natural Resources Conservation Service (NRCS), and Sure Harvest. There is no charge and lunch will be provided. For more information, contact Gary Van Sickle at CTFA, (559) 638-8260 or gvansickle@caltreefruit.com.

Winter Tree Fruit Meeting. Wednesday, December 3, 2008 at the Kearney Agricultural Center in Parlier. For more information, contact Scott Johnson at (559) 646-6547 or sjohnson@uckac.edu.

The following upcoming events are among those posted on the Postharvest Calendar at the ANR website: http://ucce.ucdavis.edu/calendar/calmain.cfm?calowner=5423&group=w5423&keyword=&ranger=3650&calcat=0&specific=&waste=yes

DATE	EVENT
02-Sep-08	**Postharvest Workgroup Meeting**
16-Sep-08	**Fresh-cut Products: Maintaining Quality and Safety - A Workshop with Emphasis on Current Research**
04-Nov-08	**3rd POSTHARVEST Unlimited**
05-Jan-09	**Frutic Chile 2009: 8th Fruit Nut and Vegetable Production Engineering Symposium**
04-Apr-09	**10th Controlled and Modified Atmosphere Research Conference**
08-Apr-09	**6th International Postharvest Symposium**
28-Apr-09	**Management of Fruit Ripening Workshop - 15th Annual**
15-Jun-09	**Postharvest Short Course (31st Annual)**

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