Effect of Cooling Delays on Fruit and Vegetable Quality

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California's electricity interruptions will most likely last for one to two hours and occur from noon to 6 PM. Power interruptions will not stop picking and field packing operations but they will halt packinghouse and refrigeration equipment during a critical time of day. Because quality begins to drop for most perishables right after harvest, the common recommendation is to begin cooling as soon as possible after harvest. Should packing and cooling operations invest in expensive standby generation to power their cooling operations during an outage or is it possible to increase the interval between harvest and cooling and not cause noticeable damage to produce? The answer is not simple and depends on the commodity, weather conditions, and other handling decisions.

Cooling delays cause reduced product quality for three main reasons: 1) allowing respiration and associated normal metabolism to continue at high rates, consuming sugars, acids, vitamins, and other constituents, 2) fostering water loss, and 3) increasing decay development. Delays may also allow increased susceptibility to ethylene damage, but ethylene concentrations are usually low near cooling facilities and ethylene does not usually cause as much damage as the other three factors. Delays can also cause undesirable product curvature and growth, but this is a problem with only a few commodities such as asparagus and green onions.

Respiration

Fresh produce consumes photosynthates that were stored in the product before harvest. Consumption rate depends on the respiratory activity of a particular commodity and its temperature. Commodities such as apples, cabbage, citrus, potatoes and table grapes have low respiration rates compared with avocados, mushrooms, asparagus and sweet corn. At temperatures above 70° to 75°F (21 - 24°C), respiration is especially high. For example at 90°F (32°C), asparagus respires three times faster than at 60°F (16°C). Temperatures above 90°F (32°C) may cause ripening disorders in commodities such as tomatoes and most tree fruits. Exposure to high temperatures and to direct sunlight can cause sunburn and sun scald injury. Cooling products from high summer field temperatures to room temperature, 70° to 75°F (21 - 24°C), significantly slows respiration.

Increased respiration caused by a few hours of cooling delay rarely causes a noticeable effect on external product quality. The consumer may detect slightly poorer eating quality and appearance and the product may have lost some nutritional value, but it is often very salable. Several tests with cantaloupe melons have shown that cooling delays up to 12 hours, even with afternoon harvested product, cause no consistent loss of visual appearance or soluble solids. However delays do cause measurable effects on quality and many produce items may not be suitable for long-distance transport or long-term storage if exposed to significant cooling delays. For example, sweet corn begins losing sweetness immediately after harvest and the rate of loss increases with increasing temperature. If cooling is delayed sweet corn should be sold quickly.

A few commodities such as peaches, nectarines, plums, Bartlett pears, and tomatoes are intentionally held at 60° to 75°F (16°- 24°C) after packing to promote ripening. If kept at a relative humidity above 85%, these commodities will actually improve in quality in a controlled ripening process. But they must be cooled after ripening has been started to slow further ripening during transport and handling. Lots prone to decay may experience increased decay losses because of ripening conditions. Although this can be considered an advantage in some situations because decayed product can be removed before shipping.

Water loss

Shriveling and the loss of fresh, glossy appearance are two of the most noticeable effects of cooling delays, particularly for commodities that lose water quickly and

show visible symptoms at low levels of water loss, like most leafy vegetables. Air temperatures 70°-75°F (21-24°C) have a particularly great effect on rate of water loss. For example, Thompson seedless grapes show visible symptoms of water loss (stem shriveling) at 3% or less. To prevent the consumer from seeing shrivel, moisture loss in the field should be kept less than 1%. At 90°F, a 1% loss can occur in about 2 hours, but at 70°F cooling can be delayed up to 12 hours.

Moisture loss is slowed by holding produce in plastic liners. Liners should be vented to prevent temperature rise caused by product respiration and damaging levels of carbon dioxide. Solid bin covers also act as a moisture barrier. Some produce items can tolerate water contact, and spraying them with water slows product moisture loss and can even rehydrate slightly wilted produce. However water remaining on the surface tends to increase decay development and water should be clean and sanitized. Many leafy vegetables can completely recover from less than a few percent water loss by contact with hydrocooler water. If hydrocooling is not available, many vegetables can be sprayed with water before forced air or vacuum cooling to regain some water and reduce loss during subsequent cooling.

Water loss is not always a detriment. Some products, like carrots, need some turgidity loss to reduce mechanical damage in handling and fresh-cut processing. Slight water loss in green onions reduces curvature problems.

Decay

Cooling delays tend to increase decay losses, although decay becomes apparent many days after the cooling delay. Damage can be minimized by applying decay control treatments within a reasonable time after harvest. For example table grapes should fumigated with sulfur dioxide within 12 hours after harvest. The process can be done with warm fruit and cooling delays may cause cold storage operators to set up facilities for fumigation separate from their forced air cooler. Another option for dealing with cooling delays in grapes to field-pack them in plastic liners and a sulfur dioxide generator pad. The liner will slow water loss and the pad will control Botrytis decay.

Free water together with high humidity speeds decay development in tree fruits and berries. For example at room temperatures, only four hours of contact with free water allows brown rot to penetrate fruit tissues. Decay-prone fruits and vegetables should be protected from prolonged water contact and very high humidity during cooling delays.

Recommendations for minimizing damage caused by cooling delays:

1. Use the following tables as a guide for acceptable time between harvest and the start of cooling. It is based on typical ambient conditions in California during normal harvest periods. Colder than normal air temperatures may allow longer delays in cooling. If the delay time added to the typical time between harvest and the beginning of cooling is greater than the allowable delay, then backup generation or refrigeration may be needed.
2. Protect produce from temperatures above 70° - 75°F (21 - 24°C). Start harvest as early as possible in the morning. On days that are predicted to be especially warm, harvesting may need to be halted when air temperatures exceed about 85°F (29°C).

   Underground vegetables are at a temperature equal to the surrounding soil temperature, which is usually much lower than daytime air temperature. Shaded fruit temperature is usually within a few degrees of air temperature, but product exposed to sunlight can be 7 to 11°F (4 - 6°C) warmer than air temperature. Shade produce after harvest to prevent excess temperature rise and sunburn and sun scald damage. Use shaded receiving areas. Even placing an empty picking box on top of a filled box protects product from temperature gain.

   Portable generators and lights allow harvest to start at 3 or 4 AM and finish before the heat of the afternoon. Night harvest has been used to a limited extent in California with melons and tables grapes. Mechanically harvested crops are usually well adapted to night harvest. Night harvest has the added benefit of allowing the commodity to begin or even finish cooling before the likely times of power interruption.

   An exception to this is citrus fruits and some leafy vegetables. High turgidity early in the morning causes the fruit to be susceptible to mechanical damage which releases toxic oil from the fruit's oil glands causing spotting of the ripened fruit. This is a problem mostly in the cooler months of the year. Leafy vegetables may be too turgid in the early morning and susceptible to stem cracking and bacterial decay.

3. Get as much product as possible to the cooler before the period of expected electrical interruptions. Trucks should make trips back to the cooler on a scheduled basis not just when they are full. If outages typically begin at 2 PM, all trucks should leave the field by 11 AM to noon so that the maximum amount of product can be in the cooler for at least some time before the cooler shuts down.
4. Protect product from moisture loss by using vented plastic liners, bin covers, or plastic containers. Some products like carrots can be sprinkled with water to reduce moisture loss during temporary holding at warm temperatures.
5. Begin decay control procedures within 8 to 12 hours after harvest. Field and packinghouse decay control procedures must be carefully applied with product exposed to cooling delays because of its increased potential for decay development.
6. Product destined for long-term storage or long distance transport should not be subjected to cooling delays.
7. Product subjected to long cooling delays should be marketed quickly.

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Table 1. Allowable maximum cooling delay between harvest and the start of initial cooling for vegetables. The delay times are only estimates. Actual field temperatures and product quality at harvest may modify the actual allowable cooling delay.

Product	Allowable delay (hours)	Disadvantage of cooling delay	Advantage of cooling delay	Comments
Vegetables				
Artichoke	8	Water loss	None	
Asparagus	4	Increased toughness; Reduced shelf-life	None	
Broccoli	4	Water & firmness loss, reduced shelf-life	None	
Cauliflower	8	Water loss	None	
Carrot	8	Water loss, loss of crispness	Reduced cracking if carrots are cold and turgid	Carrots reabsorb water during hydrocooling
Cucumber	8	Water & chlorophyll loss	None	
Dry garlic	16	None	Curing & drying	
Dry onion	16	None	Curing & drying	
Green beans	8	Water loss	None	
Green Onion	8	Texture loss	Water loss during cooling delay may reduce curvature	
Mushroom	4	Water loss, decay	None	
Potato	16	Weight loss if low relative humidity	Cure harvest wounds w/ high RH	
Peppers	16	Water loss; loss of firmness, increased decay	Reduce mechanical injury if peppers cold and turgid	
Sweetpotato	16	Weight loss if low relative humidity	Cure harvest wounds w/ high RH	
Spinach	4	Water loss	None	Can be rehydrated
Summer squash	8	Water loss	None	
Sweet corn	4	Sugar loss	None	
Tomato	16	Increased decay; color development	Color development	Apply fungicide within 8 hr., higher pulp temp. can cause decay from dump tank water absorption
Leafy Green vegetables	4 – 8	Loss of crispness, water loss	Product is subject to mechanical injury if cold & turgid	Greens reabsorb water during hydrocooling

Table 2. Allowable maximum cooling delay between harvest and the start of initial cooling for fruits and melons. The delay times are only estimates. Actual field temperatures and product quality at harvest may modify the actual allowable cooling delay.

Product	Allowable delay (hours)	Disadvantage of cooling delay	Advantage of cooling delay	Comments
Fruits and Melons				
Apple	24	Texture loss & shorter storage life	24 – 48 hr delay delays scald development in Granny Smith	
Apricot	4	Softening & decay	None	
Avocado	12	Premature ripening with high fruit maturity	None	Less delay is allowable at high temp. & with high fruit maturity
Cantaloupe	8	Water loss	None	
Grape	4 , 8 hrs at <85°F (29°C)	Shriveling, stem browning & increased decay	None	Treat with SO_2 within 12 hr.
Grapefruit	24	Increased water loss, rind defects & decay	None	Treat for decay within 24 hr.
Honeydew melon	16	Pulp softening & premature ripening	None	
Kiwifruit	6	Water loss & softening	Wound curing at 64°F (18°C) for 48 hr reduces Botrytis	
Lemon	24	Increased decay	None	Treat for decay within 24 hr.
Mandarin	8	Increased rind defects & decay	None	Treat for decay within 24 hr.
Orange	16	Increased rind defects & decay	None	Treat for decay within 24 hr.
Peach & Nectarine	8	Water loss. Decay & rapid softening in some late season lots	Fruit conditioned at 68°F (20°C) is less subject to internal browning	
Pear	16	Shrivel near stem during long term storage	Preconditioning and ripening at room temperature	
Persimmon	16	Water loss	None	
Plum	16, 48 hr if <68°F (20°C)	Water loss	Fruit conditioning	
Pomegranate	16	Water loss	None	
Strawberry and bushberries	2	Water loss, decay & loss of visual quality	None	
Sweet cherry	4	Stem shriveling & increased decay	None	
Watermelon	8	Loss of sugar & texture above 80°F (27°C)	None	