PEB Commodities, Inc.

4733 Bodega Avenue, Petaluma, CA 94952 Phone (707) 775-3100 Fax (707) 775-3232

Effect of Small Temperature Differences on Quality of Horticultural Commodities

Drs. J. K. Brecht & P. E. Brecht

8/13/2002

Horticultural commodities continue to live after harvest and experience physiological and pathological changes that can be markedly influenced by temperature. Metabolic changes in fruits, vegetables and flowers generally increase as holding temperatures are elevated. As a rule, the rate of these changes increases or decreases from 2- to 5-fold for each 10°C/18°F change in temperature. In broad terms, a 2 to 5 fold increase in the metabolic process called respiration can result in a decrease in product quality and market life of 2 to 5 fold.

In general, highly perishable commodities like strawberries and sweet corn have very high respiration rates. These high respiring commodities must be cooled quickly in order to avoid deterioration and market loss (see figures below).

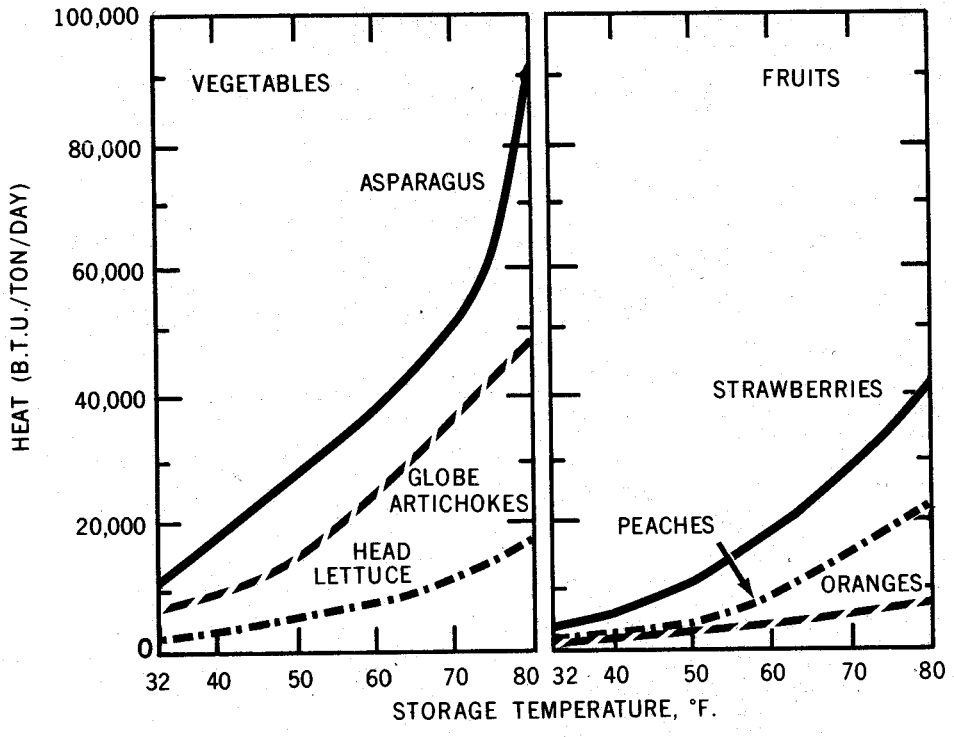


FIGURE 3.—Heat of respiration of six fruits and vegetables stored at different temperatures.

(Source: Ref. 4)

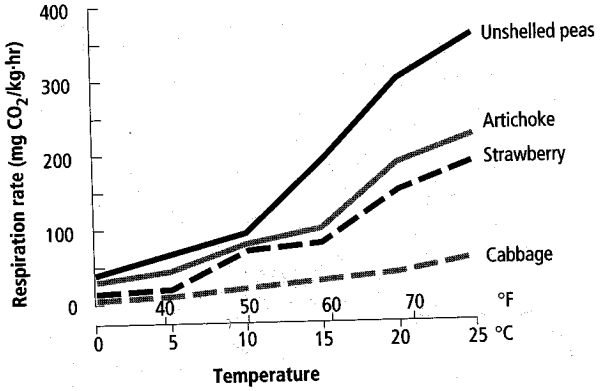


Figure 2. Effect of product temperature on respiration of several products.

(Source: Ref. 13)

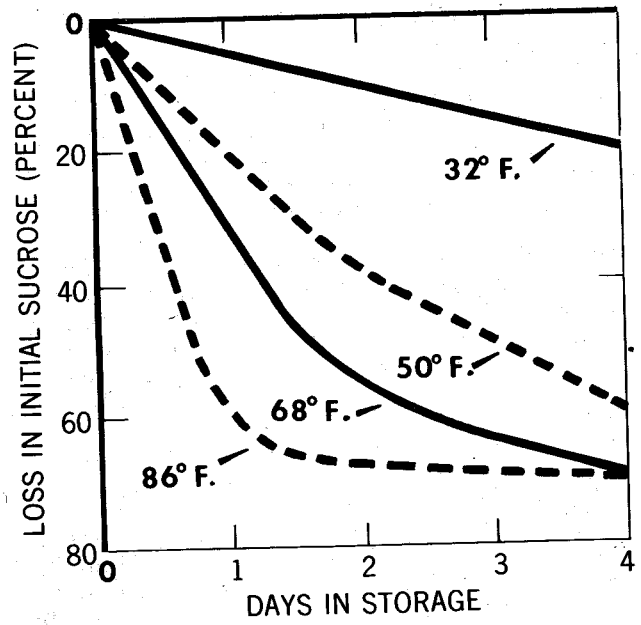


FIGURE 1.—Sucrose depletion in sweet corn stored at four temperatures. Adapted from Appleman and Arthur (28).

(Source: Ref. 4)

Deterioration is generally most serious at higher holding temperatures. For example, water loss, which is a physical process, tends to increase or decrease in a similar fashion because of the change in water vapor pressure in the plant tissues, as well as the changing capacity of air to hold water vapor as temperature changes. Because of this, it can generally be stated that any delay in initiating and expediting the cooling of fruits, vegetables and flowers after they are harvested and any temperature

increase above the optimum carrying temperature will have some negative impact on fresh produce quality and shelf life (see figures below).

Although the above facts indicate that any change in temperature or delay in initiating or hastening cooling, no matter how small, will have some effect on fruit and vegetable quality and thus shelf life, documentation of the effects of small (less than 5°C/9°F) differences in temperature are scarce. This is due to economic and logistical considerations that typically make it exceedingly difficult to carry out the research and tests that would be required to document such temperature effects. Nevertheless, there are some examples for a few extremely perishable commodities that illustrate how even small temperature differences can affect quality and shelf life.

Delays Prior to Cooling

As stated above, temperature can have a significant impact on fresh produce quality, deterioration and market life. To illustrate, a delay of only 2 hours at 30°C/86°F before precooling was sufficient to cause measurable losses in strawberry quality due to decay and more severe bruising symptoms (see figure below). In a different study, a delay of 6 hours at 30°C/86°F caused measurable losses of firmness, sugars, and vitamin C content in strawberries (Ref. 7).

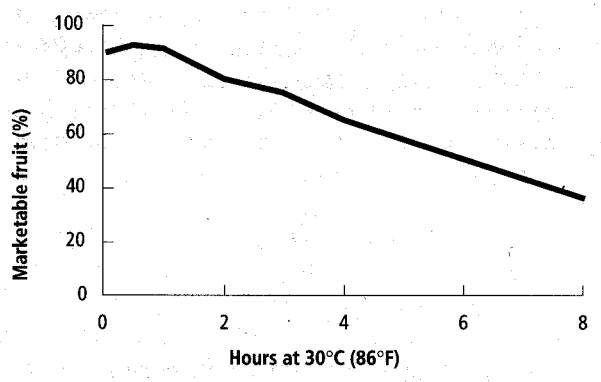
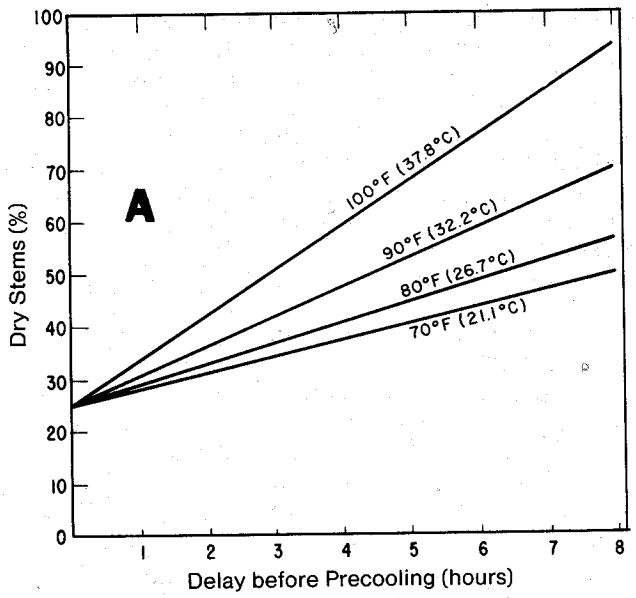


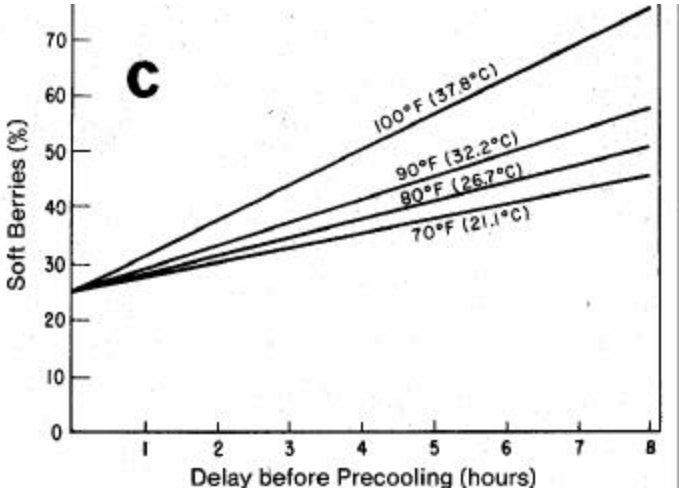
Figure 3. Effect of cooling delay on market quality of Shasta strawberries.

(Source: Ref. 13)

Similarly, a delay of 3 hours prior to cooling broccoli increased the loss of turgor (i.e., shrivel) and yellowing (Ref. 1).

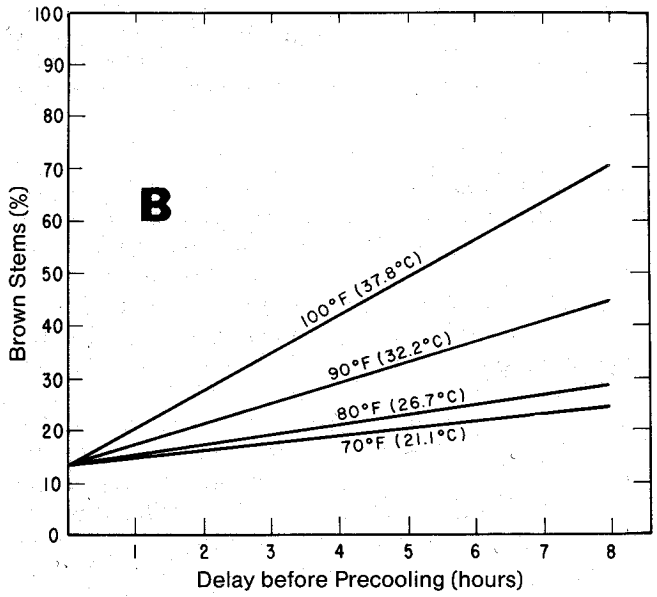
In the case of table grapes, stem drying and soft berries are directly related to temperature. The rate of quality loss due to these defects increases exponentially with increases in temperature. To illustrate, delays before cooling the grapes can cause serious stem drying/browning and berry softening. In fact, the rate of stem drying was three times greater at 38°C/100°F and the rate of brown stems was four times greater at 38°C/100°F than at 21°C/70°F (see figure 'A' below). For the same time × temperature regime, grapes held at 38°C/100°F for only 8 hours had 75% soft berries whereas grapes held at 21°C/70°F had only 45% soft berries (see figure 'C' below).

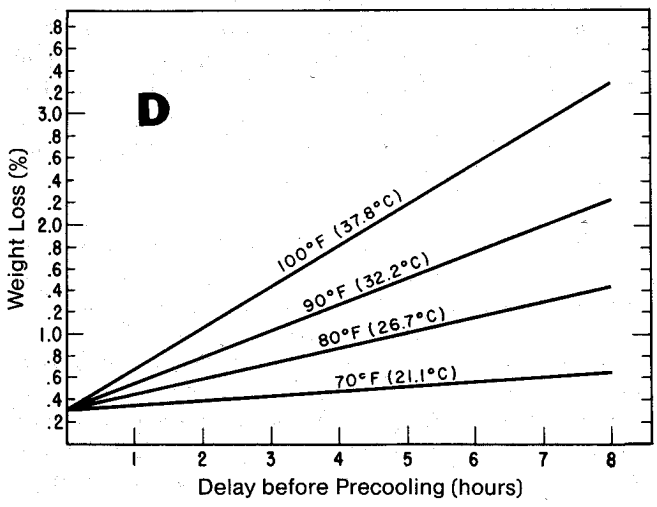




(Source: Ref. 6)

It has been shown for table grapes that varying the temperature between harvest and cooling from 21°C/70°F to 38°C/100°F for 1 to 8 hours caused linear increases in stem drying and browning, berry softening, and weight loss that were greater the higher the temperature (see figures 'A', 'B', 'C', 'D' above). Also for grapes, it has been shown that each hour of exposure to 27°C/80°F air at 20% RH results in over twice as much water loss as 1 week at 0°C/32°F at 95% RH (Ref. 10, Fig. 5).





Small Temperature Differences

Table Grapes. The importance of fast pulldown can readily be illustrated with table grapes. Harvested grapes deteriorate more in 1 hour at 32°C/90°F than 1 day at 4°C/39°F or in 1 week under transit conditions of 0°C/32°F. Consequently, promptly reducing the temperature from 32°C/90°F to 0°C/32°F can add up to 7 days to market life of table grapes.

Water loss is a serious defect for table grapes, which results from elevated temperatures. To illustrate, each hour of exposure to warm, dry air (27°C/80°F; 20% RH) resulted in over twice as much water loss as promptly reducing and holding grapes at 0°C/32°F in high (95%) humidity for 1 week (Ref. 13).

Grapes are seriously damaged due to stem shrivel with less than 2 percent weight loss. Serious stem shrivel can be avoided by fast temperature pulldown to 0°C/32°F. For example, grapes promptly cooled and loaded at 0°C/32°F lost less weight in 5°C/41°F transport than fruit cooled and loaded at 5°C/41°F (see figure '5' below).

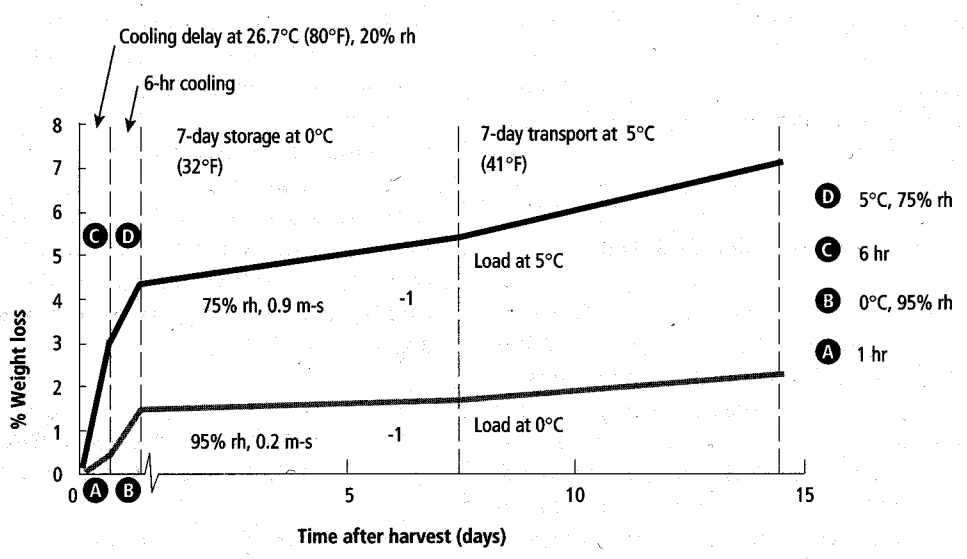


Figure 5. Table grape weight loss resulting from two different cooling and handling regimes. Lower line represents nearly ideal conditions; upper line represents the effect of poor handling.

(Source: Ref. 13)

Bean sprouts. In one report, the shelf life of bean sprouts based on the limiting factor of stem browning was reported to be 7, 5 or 4 days at 1, 3, or 6°C/34, 37, or 43°F (Ref. 2). In another report (Ref. 3), mung bean shelf life was reported to be 8.5, 5.5, 4.5, or 2.5 days at 0, 2.5, 5, or 10°C (32, 36.5, 41, or 50°F). As a result, a fast temperature pulldown from 10°C/50°F to 0°C/32°F can improve the market life of bean sprouts up to 6 days or 71%. Moreover, the USDA Handbook 66 (Ref. 4)

indicates that shelf life of sprouts kept at 0°C/32°F but exposed daily to 20°C/68°F for just 30 minutes can be reduced by 50%.

Mushrooms. The shelf life of freshly picked mushrooms based on dehydration and darkening is 5 days at 0°C/32°F, but only 2 days at 4.5°C/40°F, and 1 day at 10°C/50°F (Ref. 4). The atmosphere inside PVC plastic film-wrapped packages of mushrooms can become anaerobic within 2 to 6 hours at 20-30°C/68-86°F (Ref. 5), which has serious food safety implications due to potential growth of anaerobic microbes. Accordingly, fast temperature pulldown for mushrooms significantly lessens the potential for food poisoning and has the added benefit of improving the market life of the mushrooms up to 4 days or 80%.

Raspberry. There were measurable differences in the color of raspberries held at 0 or 4.5°C/32 or 40°F within 4 days (the first measurement) and the color change continued to change linearly for 16 days, suggesting that differences probably were present earlier than 4 days (Ref. 11).

The effects of delayed precooling on fresh red raspberry fruit during storage were determined (Ref. 12). Precooling was delayed for 0.5 to 12 hours, followed by cold storage for 8 days, with subsequent storage at 20C/68F for 24 hours. Weight loss was greater with increasing delays of precooling. Fruit that lost more weight during the delay period lost less during the subsequent 8-day storage at 0C/32F. The exception was fruit held for 12 hours before precooling. Weight loss during the final 24 hours at 20C/68F showed no pattern. Cumulative weight loss at the end of storage treatments was similar regardless of delay of precooling. Fruit strength was reduced by any delay of precooling. The effect of delayed precooling on color was not consistent in the 2 years using different cultivars. The results indicate that fruit should be precooled as quickly as possible after harvest for long-distance fresh marketing.

Quality Curves

In ongoing research in which Dr. J K Brecht is collaborating with colleagues at University Laval in Quebec, quality curves are being established for about 2 dozen fresh fruits and vegetables. This is being done by evaluating all measurable quality changes in each commodity every day or every other day (depending on relative shelf life) at 0, 5, 10, 15, 20 and 25°C/32, 41, 50, 59, 68, and 77°F. From these experiments, we are determining both the shelf life and the quality factor that limits the shelf life at each temperature. The following table shows the shelf life at these temperatures for some commodities examined so far.

	Shelf-life (days)[1]				
Commodity	0°C	5°C	10°C	15°C	20°C
Blackberry	3	2	1.5	<1.5	~1
Raspberry	4	3	2	1.5	1
Strawberry	7	5	3	2	1

Asparagus	(10) CI[2]	11	5	4	3
Green/snap bean	CI	8	6	5	3
Lettuce, Boston	21	15	13	10	6
Mushrooms	10	8	8	4	2.5
Green onion	21	17	9	5	3
Pea pod, snow pea	14	~10	9	5	2
Sweet pepper, green	CI	CI	17	14	6
Sweet pepper, red	CI	CI	14	7	4
Summer squash, yellow	CI	CI	11.5	8.5	6
Tomato vine-ripe	CI	CI	17	16	10

[1]Shelf life = days to a subjective rating of "acceptable."
[2]CI= Chilling Injury, which can render asparagus and other CI sensitive horticultural items unmarketable.
(Source: Ref. 9)

As examples of the kind of information that is being developed, the shelf life values for raspberry in the table above correspond to unacceptable darkening and development of objectionable taste or aroma as limiting factors at 0 and 5°C /32 and 41F, darkening and development of off flavor at 10 and 15°C/50 and 59F; and darkening, softening, and objectionable aroma at 20°C/68F. For yellow summer squash the shelf life values correspond to loss of firmness at 10°C/50F and loss of firmness along with development of browning at injury sites at 15 or 20°C/ 59 or 68F. From this kind of data, we can construct models to predict the rate of quality loss for any intermediate temperature as well as for fluctuating temperatures.

We have also stored snap beans and strawberries using temperature regimes that simulate temperature histories collected from transcontinental loads shipped by air or by truck in order to determine the quality effects of various levels of temperature management. The results have shown that the fluctuating and/or high temperatures that are often encountered during handling operations, even if the duration is very short, may result in rejection of a whole load of snap beans (Ref. 8) or strawberries (Ref. 10).

References

1. Brennan, P.S. and R.L. Shewfelt. 1989. Effect of cooling delay at harvest on broccoli quality during postharvest storage. Journal of Food Quality 12:13-22.

2. DeEll, J.R., C. Vigneault, F. Favre, T.J. Rennie, and S. Khanizadeh. 2000. Vacuum cooling and storage temperature influence the quality of stored mung bean sprouts. HortScience 35:891-893.

3. Lipton, W.J., W.K. Asai, and D.C. Fouse. 1981. Deterioration and CO_2 and ethylene production of stored mung bean sprouts. Journal of the American Society for Horticultural Science 106:817-820.

4. Hardenburg, R.E., A.E. Watada, and C.Y. Wang. 1986. The commercial storage of fruits, vegetables, and florist and nursery stocks. Agriculture Handbook 66, U.S. Dept. Agr., Washington, D.C.

5. Martin, S.T. and R.B. Beelman. 1996. Growth and enterotoxin production of *Staphylococcus aureus* in fresh packaged mushrooms (*Agaricus bisporus*). Journal of Food Protection 59:819-826.

6. Nelson, K.E. 1979. Harvesting and handling California table grapes for market. Publication 4095, Univ. of Calif., Agr. Sci. Publ., Berkeley, Calif.

7. Nunes, M.C.N., J.K. Brecht, A.M.M.B. Morais and S.A. Sargent. 1995. Physical and chemical quality characteristics of strawberries after storage are reduced by a short delay to cooling. Postharvest Biology and Technology 6:17-28.

8. Nunes, M.C.N., J.P. Emond, and J.K. Brecht. 2001. Temperature abuse during ground and in-flight handling operations affects quality of snap beans. HortScience 36, 510 (Abstr.)

9. Nunes, M.C.M., J.P. Emond, and J.K. Brecht. 2002. Quality curves for selected horticultural commodities as a function of the storage temperature. A research project funded by Envirotainer AB, Knivsta, Sweden.

10. Nunes, M.C.N., J.P. Emond, and J.K. Brecht. 2003. Quality of strawberries as affected by temperature abuse during ground, in-flight and retail handling operations. Paper submitted to the conference, "Quality in Chains," 6-9 July, 2003, Wageningen, The Netherlands.

11. Robbins, J.A. and P.P. Moore. 1990. Color change in fresh raspberry fruit stored at 0, 4.5, or 20°C. HortScience 25:1623-1624.

12. Robbins, J. and P.P. Moore. 1992. Fruit quality of stored, fresh red raspberries after a delay in precooling. HortTechnology 2(4):468-470.

13. Thompson, J.F., F.G. Mitchell, T.R. Rumsey, R.F. Kasmire, and C.H. Crisosto. 1998. Commercial cooling of fruits, vegetables, and flowers. Publication 21567, Univ. of Calif., Div. Agr. & Natural Resources, Oakland, Calif.