# Getting the Best Out of Strawberry Storage - What Temperature and Relative Humidity Should be Used?

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**Depending on the marketing strategy employed by growers, the proper temperature for strawberry storage may vary. Lower temperatures are important for reducing rot and decay but may negatively impact visual quality. To maintain this visual quality, a warmer storage temperature may prove valuable.**

Temperature management is regarded as the single-most important factor in minimizing deterioration of strawberry fruit and maximizing postharvest life. Higher storage temperatures result in higher respiration rates and shorter storage periods and are associated with loss of sweetness and water from the fruit (Table 1). Therefore, at Cornell, we have long advocated the use of rapid cooling of fruit to 32°F, either by passive cooling in a cold room or by forced-air cooling. At this temperature and 90 to 95% relative humidity (RH), fruit can be stored for up to 10 days depending on the variety, ripeness stage at harvest, and disease pressure.

Many New York producers have found, however, that cooling fruit to 32°F appears to be detrimental to fruit quality, especially if condensation of moisture on the fruit after removal to warmer temperatures is not controlled. Such fruit often look dull and thus less attractive to the consumer. Anecdotal reports of good quality storage of fruit at temperatures closer to 50°F, led us to compare quality of fruit kept at 33, 50 and 70°F at 75, 85 and 95% RH for up to four days. This project is part of a larger investigation into the effects of post-harvest treatment on antioxidant levels in fruit, but here we report only the effects of these treatments on the physical aspects of quality. Our objective was to provide information about the importance of temperature and RH that might be incorporated into New York industry handling protocols.

**TABLE 1**

**Respiration rates of strawberry fruit at different storage temperatures (from Mitcham, 2004).**

| Temperature (°F) | Respiration rate (mg $CO_2$ $kg^{-1}$ $h^{-1}$) |
|---|---|
| 32 | 12 to 20 |
| 50 | 50 to 100 |
| 68 | 100 to 200 |

'Jewel' strawberries were harvested at the red ripe stage at a local commercial farm and transported to the Cornell University Post-harvest Laboratory. Fruit were then sorted to remove damaged and under or oversized fruit and about 45 fruit were placed in each of 108 half gallon Mason jars (Figure 1). After allowing fruit temperatures to equilibrate to the appropriate storage temperatures, they were connected to flow boards that maintained RHs of 75, 85 or 95%. Three replicate jars were removed from each treatment and quality assessed daily for up to four days.

Quality parameters measured were:

1. Visual rating using a 1 to 5 scale where 1 is unacceptable (>50% surface showing skin damage or discoloration), 2 is bad (20–50% surface affected), 3 is acceptable (5 to 20% surface affected), 4 is good (up to 5% surface affected), and 5 is excellent. Results were expressed as an overall quality index.
2. Any fruits showing visible mold growth were considered to be decayed. Fruit decay was expressed as percentage of fruit showing decay symptoms.
3. The fruit weight at harvest and after storage was recorded and the difference was calculated and expressed as a percentage of the initial weight. Fruit exhibiting a 5% water loss are visibly shriveled.
4. Fruit surface color was measured on 10 fruits from each replicate using a chromameter (CR 100, Minolta, Ramsey, NJ, USA), to determine 'hue,' an index of redness. Three readings were taken around the equatorial region of each fruit and the average of the values was calculated. Changes in these variables indicate how rapidly fruit color changes from orange to red to dark red.
5. Firmness of 10 fruits was measured by a puncture test using a Force

Five pressure tester (Model FDV-30, Wagner Instruments, Greenwich, CT) fitted with a 7.9 mm diameter probe.

6. The soluble solids concentration (SSC) and titratable acidity (TA) were measured on juice extracted from 10 fruits by wrapping them in cheesecloth and squeezing them by hand. SSC was determined at room temperature using an Atago PR-100 refractometer (Atago Co. Ltd, Tokyo, Japan). TA was determined by titrating juice to pH 8.2 using 0.1mol/L NaOH.

## Results

The quality of strawberry fruit was best maintained at 33°F (Figure 2). On day two of storage, differences among temperatures and RHs were small. At this time, the quality ratings of fruit stored at 33, 50 and 68°F averaged 4.3, 4.1 and 4.1 units respectively, with 4 being good and 5 excellent. By three and four days after harvest, effects of both temperature and RH became apparent. The average quality rating after four days of storage across all RHs at 33°F was 4.0 units, whereas fruit kept at 50°F and 95% RH started to lose quality relative to the lower RHs. For fruit stored at 68°F, a rapid loss of quality occurred, especially in higher RHs.

A major reason for the loss of quality at higher temperatures and RHs was the development of decay (Table 2). No decay was detected in fruit stored at 33°F for four days. Water loss from the fruit was similar at all temperature and RH treatments for the first two days but was greater with warmer storage temperatures and lower RHs after three and four days in storage (data not shown).

**TABLE 2**

**Decay (%) of 'Jewel' strawberries kept at 33, 50 and 68°F and 75, 85 and 95% relative humidity (RH) for up to 4 days.**

| Temperature (°F) | RH (%) | Time after harvest (Days) 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|
| 33 | 75 | 0 | 0 | 0 | 0 | 0 |
| 33 | 85 | 0 | 0 | 0 | 0 | 0 |
| 33 | 95 | 0 | 0 | 0 | 0 | 0 |
| 50 | 75 | 0 | 0 | 0 | 0 | 1 |
| 50 | 85 | 0 | 0 | 0 | 0 | 4 |
| 50 | 95 | 0 | 0 | 0 | 0 | 7 |
| 68 | 75 | 0 | 0 | 0 | 1 | 68 |
| 68 | 85 | 0 | 0 | 0 | 12 | 100 |
| 68 | 95 | 0 | 0 | 0 | 31 | 100 |


Figure 1. Sorting out the fruit for the experiments at the Cornell Orchard laboratory.

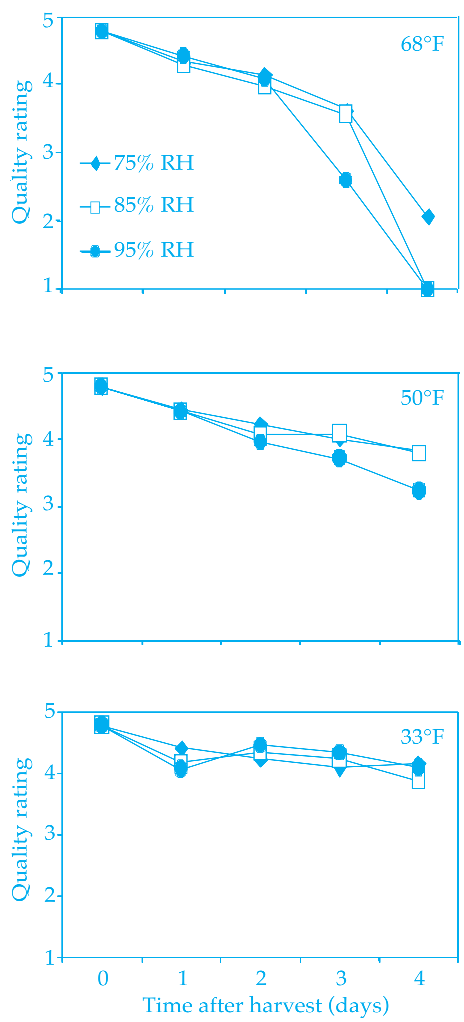


Figure 2. Quality rating (scale of 1 = poor to 5 = excellent) of 'Jewel' strawberries kept at 33, 50 and 68°F and 75, 85 and 95% relative humidity (RH) for up to 4 days.

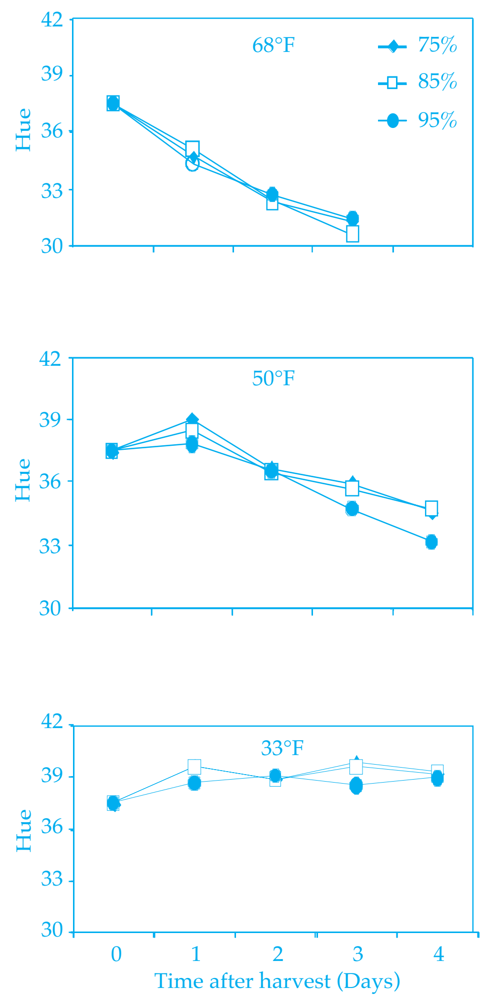


Figure 3. Hue values of 'Jewel' strawberries kept at 33, 50 and 68°F and 75, 85 and 95% relative humidity (RH) for up to 4 days. Lower values indicate greater red coloration of the fruit.

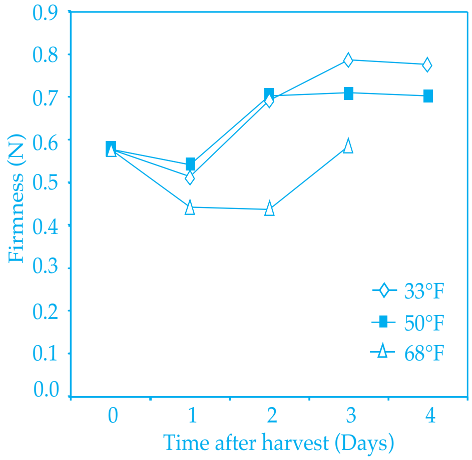


Figure 4. Firmness of 'Jewel' strawberries kept at 33, 50 and 68°F for up to 4 days. The means at each temperature represent combined data for and 75, 85 and 95% RH as there were no significant effects of this factor.

Fruit color was measured using 'hue' as an index of redness. As 'hue' values decline the fruit color becomes redder. At 68°F the fruit turned redder more rapidly than at colder temperatures (Figure 3), as would be expected from faster ripening at warm temperatures. In contrast, fruit stored at 33°F maintained color close to those measured at harvest. The reddening of fruit held at 50°F was somewhat intermediate between the two temperature extremes but was slightly faster at 95% RH than at 75 and 85% RH.

Firmness of the fruit was also measured (Figure 4). There was no effect of RH and therefore the data are combined for each temperature. At 33 and 50°F, firmness changed little for a day and then fruit became firmer. This firming effect is often observed, and although it is not well understood, it is likely to result from physical effects of colder temperatures. At 68 °F, the firmer fruit at day three may be an artifact due to decay of softer fruit that were therefore not measured.

Sugar levels as indicated by SSC declined over time and to a greater extent at 50 and 68°F (6.5% and 6.4%, respectively) than at 33°F (6.8%), probably due to the lower respiration rates at the lowest temperature. Measurements of titratable acidity and pH of juice from these berries showed no effect by either temperature or RH (data not shown).

## Conclusions

The best temperature for maintaining quality of strawberry fruit was 32°F, where decay and ripening were delayed most. However, if growers want to avoid problems with condensation and loss of visual quality that can be observed at this temperature when fruit are warmed for marketing, keeping fruit at a warmer temperature, such as 50 °F, for a short time may be acceptable. Therefore, depending on the marketing strategy employed by growers, avoiding chilling temperatures may be a useful option.

An important caveat for this recommendation is that the storage time at warmer temperatures is limited; in the experiment described here, two days, or at the most, three days, if the RH is not high. Clearly, high RHs are detrimental at warmer temperatures, presumably because fungal growth is stimulated. These time periods may be longer if fruits are less ripe, but shorter if decay potential is higher.

## Literature Cited

Mitcham, E. J. 2004. Strawberry. In: Gross, K. C. C. Y. Wang and M. Saltveit. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops. An Adobe Acrobat pdf of a draft version of the forthcoming revision to U. S. Department of Agriculture, Agriculture Handbook 66 on the website of the USDA, Agricultural Research Service, Beltsville Area <http://www. ba. ars. usda. gov/hb66/index. html>

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