

Cooling Strawberries—Going Halfway May Be Enough

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The potential for growth of the market for locally grown strawberry fruits is increasing in New York, and represents an important supplement to traditional pick-your-own operations.

“Strawberry fruits should be cooled quickly and kept as close to 32°F as possible for maximum storage potential. However, warmer storage temperatures of 50°F using fruits harvested at the white tip maturity stage store well. These fruits ripened when stored at 50°F and they had higher concentrations of antioxidant components than fruit harvested at the red ripe stage.”

However, much of the information about storage and handling of strawberries that is available in books and on the web is oriented towards large-scale storage and transport of fruits from California and Florida. For

example, rapid cooling and carbon dioxide treatment of strawberries represent methods that are not easily applicable to many New York farms, especially with our short harvest periods that can limit economic decisions such as investment in coolers and other equipment. Also, many growers have been reluctant to cool strawberries to the recommended storage temperature of 32°F because it can result in condensation on the fruit surface when they are warmed after storage. The fruits then are duller looking and less attractive to consumers. Unfortunately, however, during the harvest season it is not uncommon to find New York strawberries in supermarkets and other retail outlets that are unattractive because they look over-ripe. Even though they have great flavor, they do not compare well visually with strawberries from elsewhere.

We have been investigating the harvesting and handling of strawberry fruits in a way that is more typical of the New York industry. In addition to assessment of physical quality attributes, we have studied the effects of factors such as storage temperature on the nutritional quality of the fruits. The strawberry fruit is well recognized for its potential health benefits, well beyond its contribution to vitamin C in the diet. Anthocyanins, the pigments that contribute to red color of the fruit, have potent antioxidant activities, as do other phenolic compounds and phytochemicals. Moreover, the activity of individual phytochemicals is thought to be additive and/or synergistic, and the contribution of these, both known and unknown, can be assessed by measuring the total antioxidant activity.



Figure 1. Strawberries at white tip (left) and red ripe (right) stages of maturity.

Meeting the needs of retail operations requires attention to factors such as variety selection, harvest management and storage. In an earlier *New York Fruit Quarterly* article (Shin et al., 2005), we reported that ‘Jewel’ strawberries harvested at the red ripe stage could be stored at 50°F for short periods of time with acceptable appearance. More detailed studies of the fruits showed that their nutritional status might also be better at 50°F compared with that at 32°F (Shin et al., 2007). The storage period in that experiment was limited to four days, and we followed up this study with increased storage periods up to 12 days. We compared the physical and nutritional quality of ‘Jewel’ fruits harvested at two maturity stages (white tip and red ripe), two storage temperatures (38 and 50°F), and two relative humidities (65 and 95% RH). The red ripe stage of fruits was more advanced, i.e. redder, in the current study than in that used by Shin et al. (2005). A full summary of the current study is available (Shin et al., 2008), but here we highlight the main findings. The effect of variety is not considered here but can be an additional critical factor in the length of storage that can be achieved.

Methods

Strawberry fruits were harvested at the white tip and red ripe stages (Figure 1) at a local commercial farm and transported to the Cornell University Postharvest Laboratory. Fruits were then sorted to eliminate any with damage, and selected for uniform size and color. About 35 fruits were placed in a series of 1.9 L Mason jars, which were weighed before and after addition of fruits. After allowing the fruits to equilibrate to either 38° or 50°F for 2 h, they were connected to flow boards where the air was bubbled through water and glycerol mixtures to maintain 65% or 95% RH. Three replicate jars were removed from each temperature

and RH treatment at three-day intervals for up to twelve days and the quality of the fruits was assessed.

The fruits were then evaluated individually for quality on a scale of 1-5 according to the percentage of surface area damaged, where: 1= unacceptable (>50% surface showing skin damage or discoloration), 2= bad (20–50 % surface affected), 3= acceptable (5 to 20% surface affected), 4= good (up to 5% surface affected), and 5= excellent. Results were expressed as an overall quality index.

Samples from 10 fruits were frozen by slicing into liquid nitrogen. They were kept at -80°C until used for extraction and measurement of total phenolic, flavonoid, anthocyanin, ascorbic acid concentrations and total antioxidant activity. These compounds were measured using routine methods in our laboratory as described by Shin et al. (2008).

Results

The quality of the strawberries was affected greatly by maturity stage at harvest and by storage temperature (Figure 2). Quality of fruits harvested at the white tip stage of ripeness declined more rapidly at 50°F than at 38°F . However, taking a quality rating of 3 as the minimum acceptable by consumers, white tip fruits kept at 50°F were still acceptable at nine days of storage. In contrast, overall quality loss of red ripe fruits occurred rapidly at both temperatures and faster at 50°F than at 38°F .

Negligible decay was found in white tip and red ripe stage berries stored at 38°F . However, at 50°F , and especially at higher RH, decay was a factor. At 9 and 12 days of storage, decay incidence reached 5 and 25% in white tip berries, and 29 and 72% in red ripe berries, respectively.

The red color in strawberries results from anthocyanin synthesis in the fruit. At harvest, the anthocyanin concentrations of red ripe fruits were about five times higher than that of the white tip fruits (Figure 3).

The anthocyanin concentrations of the white tip fruits kept at 38°F did not change much over time (Figure 3). In contrast, fruits kept at 50°F developed red color. There was no effect of RH. In red ripe fruits, the anthocyanin concentrations were already close to maximum levels at harvest. The concentrations remained stable or decreased slightly during storage until day nine, before decreasing rapidly at 50°F , and to a greater extent at 95% RH than at 65% RH.

At harvest, vitamin C as indicated by total ascorbic acid concentrations in the white tip and red ripe fruits, were 420 and 453 mg kg^{-1} , respectively (Figure 4). Ascorbic acid concentrations in white tip fruits increased slightly over time and were higher at 50°F than at 38°F , but they were not affected by RH during the storage. Concentrations of the red ripe fruits were maintained until day nine and then decreased more rapidly at 50°F than at 38°F by day 12. RH did not affect ascorbic acid concentrations of fruits.

At harvest, the flavonoid concentrations of the white tip fruits were greater than those at the red ripe stage (Fig-

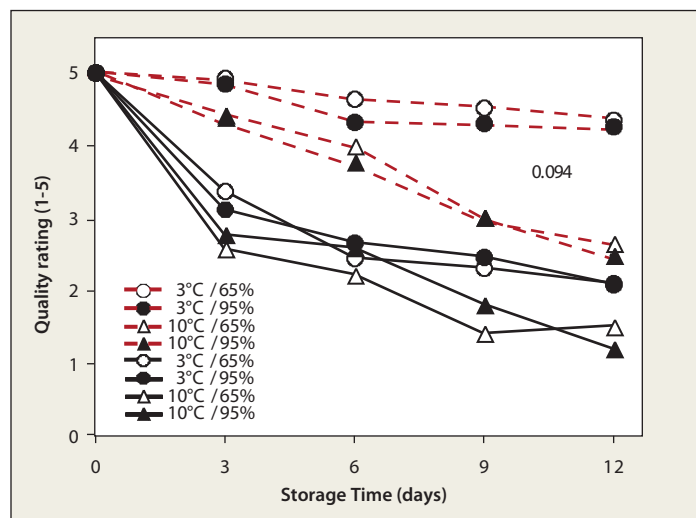


Figure 2. Quality index of 'Jewel' strawberries harvested at the white tip stage (-----) and red ripe stage (—) and stored at 38°F (3°C) or 50°F (10°C) at 65% or 95% relative humidity. The quality index is a 1–5 scale according to the percentage of surface area damaged, where 1= unacceptable (>50 % surface showing skin damage or discoloration), 2= bad (20–50 % surface affected), 3= acceptable (5 to 20 % surface affected), 4= good (up to 5 % surface affected), and 5= excellent. The LSD value at $P=0.05$ for comparison of means is 0.094 mg Kg^{-1} .

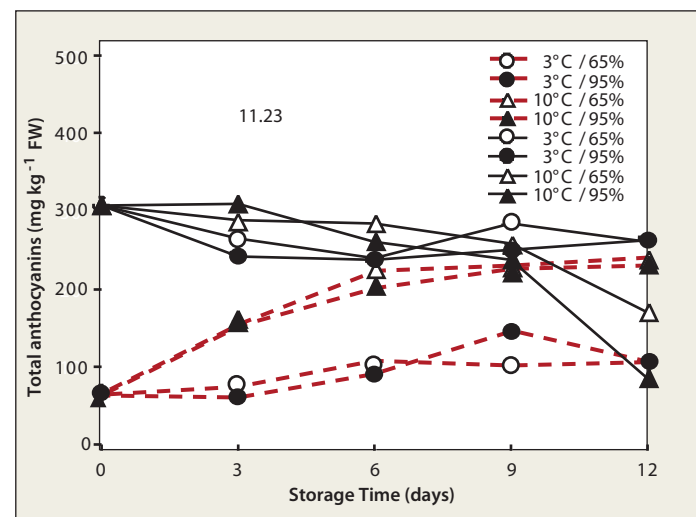


Figure 3. Total anthocyanin contents of 'Jewel' strawberries harvested at the red ripe stage (—) and white tip stage (-----) and stored at 38°F (3°C) or 50°F (10°C) at 65% or 95% relative humidity. The LSD value at $P=0.05$ for comparison of means is 11.23 mg Kg^{-1} .

ure 5). The total flavonoid concentrations of the white tip fruits during storage were slightly higher, averaging 856 and 807 $\text{mg catechin equivalents kg}^{-1}$ at 65% and 95% RH, respectively. The total flavonoid concentrations of the red ripe fruits were affected by temperature and RH on day 12; at 50°F , concentrations declined more at 95% RH than at 65% RH.

The phenolic concentrations were also higher in white tip fruits than in red ripe fruits at harvest and during storage (Figure 6). The phenolic concentrations in the white tip fruits were stable during storage, while they decreased

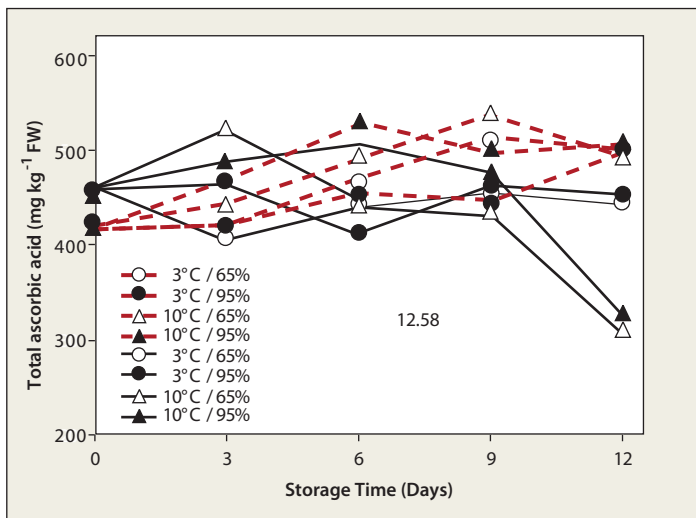


Figure 4. Total ascorbic acid contents of 'Jewel' strawberries harvested at the white tip stage (-----) and red ripe stage (—) and stored at 38°F (3°C) or 50°F (10°C) at 65% or 95% relative humidity. The LSD value at P=0.05 for comparison of means is 12.58 mg Kg⁻¹.

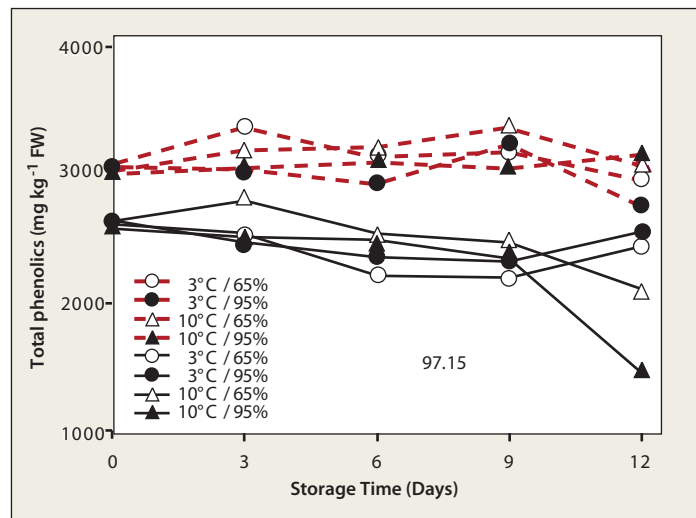


Figure 6. Total phenolic contents of 'Jewel' strawberries harvested at the white tip stage (-----) and red ripe stage (—) and stored at 38°F (3°C) or 50°F (10°C) at 65% or 95% relative humidity. The LSD value at P=0.05 for comparison of means is 97.15 mg Kg⁻¹.

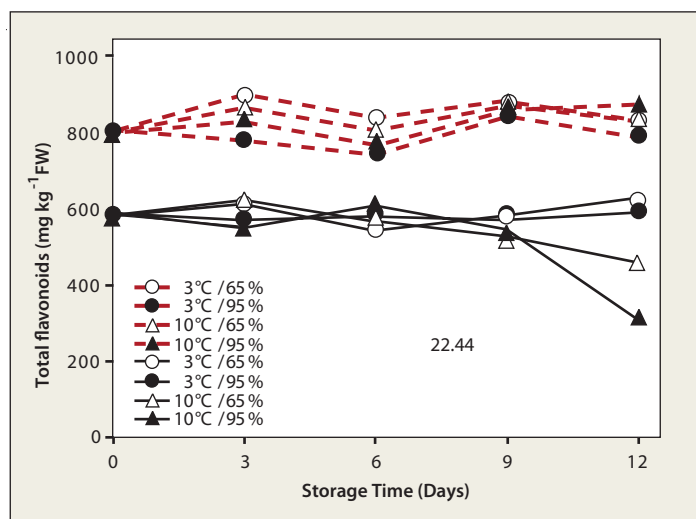


Figure 5. Total flavonoid contents of 'Jewel' strawberries harvested at the white tip stage (-----) and red ripe stage (—) and stored at 38°F (3°C) or 50°F (10°C) at 65% or 95% relative humidity. The LSD value at P=0.05 for comparison of means is 22.44 mg Kg⁻¹.

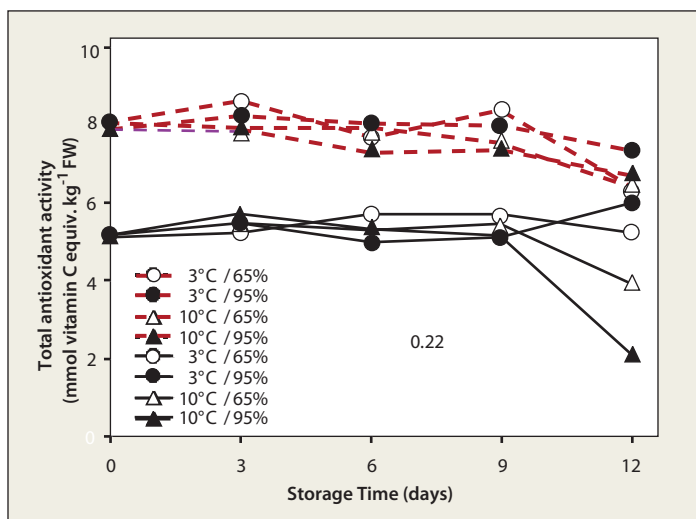


Figure 7. Total antioxidant activity of 'Jewel' strawberries harvested at the white tip stage (-----) and red ripe stage (—) and stored at 38°F (3°C) or 50°F (10°C) at 65% or 95% relative humidity. The LSD value at P=0.05 for comparison of means is 0.22 mmol vitamin C equiv. Kg⁻¹.

rapidly at 50°F in the red ripe fruits, and to a greater extent at 95% RH than at 65% RH on day 12.

At harvest, total antioxidant activity of the white tip fruits was higher than the red ripe fruits (Figure 7). Total antioxidant activity of the white tip fruits was only slightly affected by temperature but not by RH. Effects of temperature on total antioxidant activity of red ripe fruits were also small, except that activity of fruits stored at 50°F declined more rapidly on day 12 than those stored at 38°F. Overall antioxidant activities of the red ripe fruits stored at 65 and 95% were 5.26 and 5.00 mmol of vitamin C equivalents kg⁻¹, respectively. The antioxidant activity in fruits declined rapidly at 50°F on day 12, and to a greater extent at 95% RH than at 65% RH.

Discussion

If the goal of the grower is to maintain storage periods as long as possible, then temperatures should be as close to 32°F as possible. Lower storage temperatures slow down respiration and other metabolic changes such as the rate of color change. These effects are more critical for fruits in a more mature stage at the time of harvest. The benefit of low temperature storage in the red ripe fruits used in the current study was limited suggesting that very ripe fruits should be marketed quickly.

Forced air cooling is one strategy that can be employed to cool fruits rapidly, but only if cold rooms with high RH (90-95%) are available, along with good monitoring of temperatures to ensure that fruits are not cooled more than

within 5°F of the desired temperature. Otherwise, the fruit can become dehydrated. A useful reference for growers interested in forced-air cooling is Fraser (1991). The other concern of New York growers about using low storage temperatures is the condensation and dull appearance that develops after fruits are warmed. One strategy to avoid this problem involves labor and plastic. Condensation on the fruits can be avoided by covering flats or pallets with plastic before they are removed from cold storage. The plastic must be left on until the fruit warm to a temperature above the dew point. If fruits are re-cooled, the plastic also must be removed, as leaving the plastic in place will cause condensation to form inside the bag and create an environment for fungal decay.

The results presented here illustrate an important option for growers if cooling facilities are limited. The first is use of a moderate temperature such as 50°F, but only if fruit maturity at harvest is considered. Storage potential of very ripe strawberries is limited and further reduced at 50°F. Fruits harvested at the white tip stage, in contrast, have an extended storage life and at 50°F continue to ripen as indicated by red color development. A limitation of using this storage temperature is the potential for a higher incidence of decay. In our studies, decay was not detected until day nine of storage, but incidence could be affected by preharvest factors, including weather.

Strawberries are non-climacteric fruits and have limited ripening capability after harvest. Therefore, fruits harvested at the white tip stage do not necessarily develop the full flavor of fruit harvested at the full red ripe stage. Unfortunately, there is always a compromise between quality and storage potential—fruits that are harvested early, often do not develop full aroma, flavor and other quality aspects but store for longer periods of time, whereas fruit harvested with full quality characteristics have short storage potential. These two conflicting goals apply to many horticultural products and the balance that is chosen by the grower will be a function of the market segment that is desired. For best retail quality, earlier harvest is essential unless high rates of product turnover can be guaranteed.

It is interesting that an earlier harvest results in higher concentrations of compounds that are associated with health benefits of the fruit, and that these remain essentially unchanged unless fruit quality deteriorates. Total flavonoids, total phenolics, and total antioxidant activity were higher at the white tip than at the red ripe stage of ripening. Total flavonoid and phenolic concentrations, and total antioxidant activity, remained relatively stable for 12 days in fruits harvested at the white tip stage, and nine days for those harvested at the red ripe stage. Total anthocyanins and ascorbic acid concentrations were highest in the red ripe fruit, but ascorbic acid is thought

to be a minor component of overall antioxidant activity. Interestingly, correlations among quality ratings with total antioxidant activity were high. Within the various compounds, total antioxidant activity was highly correlated with total flavonoid and phenolic concentrations, but less so with anthocyanin and ascorbic acid concentrations. It has not been established whether these compounds have a direct relationship with human health. We were not able to find differences in antiproliferative activities among fruit extracts from different maturity and storage periods on cancer cell proliferation. The bottom line is that strawberries are healthy and consumers should be encouraged to eat them along with other fruits and vegetables.

In summary, fruit kept at colder temperatures resulted in the longest storage life, but even moderate temperatures of 50°F resulted in good maintenance of fruit quality if harvested at the white tip stage of ripeness. RH had little effect on any attributes assessed in this study. Less ripe berries also had higher total phenolic and flavonoid concentrations, and antioxidant activity than riper berries, and these differences were largely maintained during storage. This stability, exhibited except where fruit quality deteriorated to a major extent, contrasted with total anthocyanins and ascorbic acid. Although individual components of any antioxidant class were not measured and therefore more subtle changes were not detected, the data suggest that the flavonoids and phenolics are less actively modified during storage than anthocyanins and ascorbic acid. Overall, higher visual quality of the berries during storage was associated with harvest of less ripe fruit, and also with higher concentrations of total flavonoid and phenolic concentrations, and antioxidant activity.

Acknowledgements

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