The Failure of Postharvest Treatments to Control Firm Flesh Browning in Empire Apples.

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The development of firm flesh browning has proven to be a major limitation to the long-term storage of Empire apples for many years. Further complicating the effective management of this disorder is its sporadic incidence. Observations of the occurrence of the disorder have been used to establish a link to temperatures during July and August. Cool temperatures during these months generally increase firm flesh browning during storage. In a companion article in this issue, background information about firm flesh browning and other storage disorders of Empire apples is described (Watkins, 2010). Also, in a recent New York Fruit Quarterly article (James et al., 2010a) we highlighted the importance of early harvest as an important strategy to minimize risks of developing firm flesh browning and senescent breakdown. In addition, research has shown that carbon dioxide concentration in CA storage also influences the development of firm flesh browning. Increasing carbon dioxide concentrations in storage increases the incidence of firm flesh browning. However, elevated carbon dioxide also contributes to maintenance of flesh firmness of the fruit. Standard CA storage recommendations of carbon dioxide levels of 1-2% along with 2% oxygen represent a compromise between levels too low to maintain flesh firmness and higher levels that increase the incidence of the disorder (Watkins, 2010).

As part of an extensive series of trials, we have investigated the impact of several postharvest management strategies on the development of firm flesh browning. Fruit were harvested from trees at Cornell Orchards. Then, samples were cooled overnight before being left untreated or treated with 1ppm SmartFresh (1-MCP). Fruit were stored in experimental chambers under CA conditions of 2% O₂ / 2% CO₂. Flesh browning data (regardless of severity) are presented as the % of fruit with symptoms. Only firm flesh browning results will be reported here.

Modification of the Storage Temperature.
Fruit were stored at 33, 35 or 38°F, or subjected to either a stepwise cooling treatment (8 weeks at 38, 8 weeks at 35°F, then 6 months at 33°F) or a stepwise warming treatment (8 weeks at 33°F, 8 weeks at 35°F, then 6 months at 38°F).

Among samples not treated with SmartFresh, the incidence of firm flesh browning was lowest (3%) in fruit stored at 38°F (Figure 2) and highest in fruit that received the stepwise warming treatment (27%). The incidence of firm flesh browning was similar in untreated fruit samples that were either stored at 33°F (23%), stored at 35°F (24%), or received the stepwise cooling treatment (18%). These results were consistent with the theory that firm flesh browning in Empire apples is the result of a chilling injury. However, the use of SmartFresh was found to modify this relationship. When SmartFresh was applied prior to placing fruit into long-term
storage, the highest incidence of flesh browning (52%) was found in fruit stored at 38°F, opposite to results observed in untreated fruit. The incidence of flesh browning in SmartFresh treated fruit was also high in samples stored at 33°F (46%) and lowest in fruit that received the stepwise cooling treatment (24%). Aside from modifying the relationship between storage temperature and the incidence of flesh browning, application of SmartFresh resulted in increased levels of browning in all storage temperatures tested.

While the lowest firm flesh browning incidence was observed in untreated samples that were stored at 38°F, this temperature is not recommended for the long-term storage of Empire apples. As mentioned earlier, storage at this temperature both accelerates firmness loss and increases the incidence of senescent breakdown. It was hoped that the firmness benefits of SmartFresh would mitigate the disadvantages of warmer storage temperatures. However, this was not found to be the case.

Timing of SmartFresh Application
Fruit samples were left untreated, treated with SmartFresh at harvest, or treated with SmartFresh after 4 or 8 months of CA storage before return to CA storage for the remainder of the storage period.

The incidence of flesh browning was highest (55%) in fruit that were treated with SmartFresh at harvest (Figure 3) and lowest in fruit that were treated with SmartFresh after 8 months of storage (26%). However, any benefits of this delay on browning were associated with unacceptable loss of fruit condition, specifically firmness.

Postharvest application of Calcium and DPA
Fruit were untreated or treated with SmartFresh at harvest followed by 15% DPA (2000ppm), 12.1% calcium (2100ppm), 24.2% calcium (4200ppm), or combinations of 15% DPA and 12.1% calcium or 15% DPA and 24.2% calcium. DPA (Shield DPA, Pace International, Wenatchee, WA) and calcium (Opti-CAL, Pace International, Wenatchee, WA) were applied by submerging fruit in the concentrations indicated for 1 minute. Fruit quality assessments were carried out following 10 months CA storage (2% CO₂, 2% O₂) and 7 days at 68°F.

For untreated fruit, the incidence of flesh browning was lowest (26%) in fruit treated with 2100ppm calcium (Figure 4) and highest in fruit treated with a combination of DPA with 2100ppm calcium (51%). There was little difference in the incidence of flesh browning in untreated fruit between the control treatment and any of the dips in isolation. For all treatments, the incidence of flesh browning was highest in fruit treated with SmartFresh compared with untreated fruit. The differences were greatest in fruit treated with DPA or calcium alone and least in combination treatments.

Delayed establishment of CA
Fruit were untreated or treated with SmartFresh. One set of fruit was placed directly into CA storage while a second set of fruit was held in 32°F air storage for 3 weeks before establishing CA conditions.

In untreated fruit samples, the incidence of flesh browning was markedly lower when establishment of CA conditions was delayed by 3 weeks (8% delayed, 51% no delay) (Figure 5). However, when SmartFresh was applied prior to storage, this beneficial effect on flesh browning was lost. There was no significant difference in the incidence of flesh browning between the control treatment (45%) and the delayed CA treatment (52%).
Low humidity storage

Fruit were untreated or treated with SmartFresh. One set of fruit was placed into regular CA conditions while the other set was placed into low humidity CA storage.

In untreated fruit samples, there was a reduction in the incidence of flesh browning when the fruit were stored in low humidity (18%) compared to the control (50%) (Figure 6). There was no significant difference between untreated and SmartFresh treated fruit in control conditions. However, SmartFresh treatment resulted in an increased incidence of flesh browning in the low humidity storage samples (32% vs 18%).

Summary

Most methods that have been used to reduce chilling related flesh browning disorders result in unacceptable softening or development of senescent type disorders. Our hope was that these methods could be used for SmartFresh-treated fruit without suffering loss of condition. However, no single method included in this study resulted in acceptable control of firm flesh browning.

Modification of the storage temperature

• Storage at warmer temperatures reduces the incidence of flesh browning; this effect was lost with the application of SmartFresh.

Timing of SmartFresh application

• Delaying the application of SmartFresh after harvest can reduce the incidence of browning.

Postharvest application of calcium and DPA

• Application of calcium and DPA alone or in combination did not reduce the incidence of flesh browning.

Delayed establishment of CA conditions

• Delaying the establishment of CA conditions is effective at reducing the incidence of flesh browning; this effect was lost with the application of SmartFresh.

Low humidity storage

• Storage in CA at low humidity was found to be effective at reducing the incidence of flesh browning; this effect was reduced in SmartFresh-treated fruit.

We conclude that no currently acceptable postharvest treatment is available to the New York apple industry to reduce firm flesh browning either with or without SmartFresh application.

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Bibliography


Hannah James is a postdoctoral associate who works with Chris Watkins on fruit browning. Jacqueline Nock is a research support specialist who works with Chris Watkins on post harvest storage of fruits and Chris Watkins is a professor and associate director of Cornell Cooperative Extension who leads Cornell's program in postharvest biology of horticultural crops.
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