THREE YEARS OF STORAGE RESEARCH ON PENNSYLVANIA HONEYCRISP—IMPLICATIONS FOR GROWERS AND PACKERS

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Growers and other cooperators

Rich Marini
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- Jackie Nock
- The many NY cooperating growers and storage operators

The funding

- NY Apple R&D Program
- NYFVI
- AgroFresh
- Federal Hatch funding (Multistate)
Honeycrisp recommendation

- **Condition at 50F for 7 days and then store at 38F.**
  - *Conditioning to prevent soft scald, but...*
  - *Growing region factors? (CH vs HV/PA)*

<table>
<thead>
<tr>
<th>Trt</th>
<th>Soggy bkdn (%)</th>
<th>Soft scald (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>33°F</td>
<td>18a</td>
<td>62a</td>
</tr>
<tr>
<td>38°F</td>
<td>1b</td>
<td>9cd</td>
</tr>
<tr>
<td>Delay, 33°F</td>
<td>2b</td>
<td>14c</td>
</tr>
<tr>
<td>Delay, 38°F</td>
<td>0b</td>
<td>2d</td>
</tr>
</tbody>
</table>

But knowns and unknowns... Influenced by CH
Objectives

- To understand the dynamics of bitter pit and soft scald development
- To develop prediction methods for bitter pit development
- To develop prediction methods for soft scald development

- Controlled atmosphere storage of Honeycrisp apples – an update
THE DYNAMICS OF BITTER PIT AND SOFT SCALD DEVELOPMENT
Bitter pit

Soft scald
The dynamics of bitter pit and soft scald development (2013/2014)

- Fruit from 4 PA orchard blocks, 6 HV orchard blocks and 12 WNY orchard blocks
- Minerals 3 weeks before harvest and at harvest, maturity assessment, and then storage at 38°F for 4 months
- Stored at 38°F without conditioning
- Bitter pit and soft scald development assessed on stored fruit at monthly intervals for 4 months

Only PA and WNY shown for illustration; CH comment
Bitter pit (PA): 2013 harvest
Bitter pit (WNY): 2013 harvest
Mineral relationships

- In progress

- Need collective years of data

- Some results promising, e.g. Mg/Ca ratio
Bitter pit incidence and peel Mg/Ca

\[ y = 13.326x - 29.696 \]

\[ R^2 = 0.6868 \]
Dynamics of change

- Bitter pit usually near maximum after a month of storage, but exceptions in PA fruit.
- Soft scald does not become apparent until after 1 month of storage.
- Mineral relationships potentially strong.
Effects of conditioning on bitter pit and soft scald of fruit stored at 38°F (2014/2015)

- Honeycrisp apples from PA (2 orchards), HV (3 orchards), WNY (2 orchards), and Champlain (3 orchards).
- Fruit untreated or conditioned at 50°F before storage at 38°F
- Storage for 20 weeks plus 7 days at 68°F
Bitter pit (%) 2014: 38F with and without conditioning

38F

Conditioning + 38F
Effects of conditioning on bitter pit (%) after 20 weeks of air storage

<table>
<thead>
<tr>
<th></th>
<th>38°F</th>
<th>Cond. + 38°F</th>
<th>% Increase over ‘no conditioning’</th>
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<tbody>
<tr>
<td>PA1</td>
<td>21</td>
<td>37</td>
<td>76</td>
</tr>
<tr>
<td>PA2</td>
<td>9</td>
<td>16</td>
<td>78</td>
</tr>
<tr>
<td>HV1</td>
<td>42</td>
<td>67</td>
<td>60</td>
</tr>
<tr>
<td>HV2</td>
<td>29</td>
<td>49</td>
<td>69</td>
</tr>
<tr>
<td>HV3</td>
<td>13</td>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td>WNY1</td>
<td>8</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>WNY2</td>
<td>18</td>
<td>27</td>
<td>50</td>
</tr>
<tr>
<td>CH1</td>
<td>41</td>
<td>63</td>
<td>54</td>
</tr>
<tr>
<td>CH2</td>
<td>4</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>CH3</td>
<td>9</td>
<td>12</td>
<td>33</td>
</tr>
<tr>
<td>Average</td>
<td>19</td>
<td>31</td>
<td>63</td>
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</table>
Effect of conditioning on bitter pit incidence (%)
Effects of conditioning on soft scald (%) after 20 weeks of air storage

<table>
<thead>
<tr>
<th></th>
<th>38°F</th>
<th>Cond. + 38°F</th>
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<tbody>
<tr>
<td>PA1</td>
<td>3.5</td>
<td>0</td>
</tr>
<tr>
<td>PA2</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>HV1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HV2</td>
<td>7.3</td>
<td>0</td>
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<tr>
<td>HV3</td>
<td>2.2</td>
<td>0</td>
</tr>
<tr>
<td>WNY1</td>
<td>4.2</td>
<td>0</td>
</tr>
<tr>
<td>WNY2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CH1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>CH2</td>
<td>3.9</td>
<td>0</td>
</tr>
<tr>
<td>CH3</td>
<td>0.2</td>
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<tr>
<td>Average</td>
<td>2.4</td>
<td>0</td>
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Effects of conditioning on senescent breakdown(%) after 20 weeks of air storage

<table>
<thead>
<tr>
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<th>38°F</th>
<th>Cond. + 38°F</th>
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<tbody>
<tr>
<td>PA1</td>
<td>28</td>
<td>16</td>
</tr>
<tr>
<td>PA2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>HV1</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>HV2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>HV3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WNY1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WNY2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>CH1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>CH2</td>
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<tr>
<td>CH3</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Average</td>
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Effects of conditioning on skin wrinkling (%) after 20 weeks of air storage [2014/15]

<table>
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<th>Cond. + 38°F</th>
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</thead>
<tbody>
<tr>
<td>PA1</td>
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<td>38</td>
</tr>
<tr>
<td>PA2</td>
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<td>0</td>
</tr>
<tr>
<td>HV1</td>
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<td>0</td>
</tr>
<tr>
<td>HV2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>HV3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WNY1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WNY2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CH1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CH2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CH3</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>
Effects of conditioning on CO$_2$ injury (%) after 20 weeks of air storage [2014/15]

<table>
<thead>
<tr>
<th></th>
<th>38°F</th>
<th>Cond. + 38°F</th>
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</thead>
<tbody>
<tr>
<td>PA1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PA2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HV1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HV2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>HV3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>WNY1</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>WNY2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CH1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>CH2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CH3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
What all our experiments tell us!

- Variation among orchards for both bitter pit and soft scald – recurrent theme
- Conditioning of fruit consistently reduces soft scald development, but aggravates bitter pit development.
- Storage at 38°F can result in higher bitter pit development compared with 33°F.
- Lower bitter pit potential results in lower losses due to conditioning

- Other storage problems can occur and may have regional influence.

- Storage of Honeycrisp at 33°F is risky regardless of conditioning (beyond 1-2 months), but results in minimal bitter pit.
  - Off setting risks – which is best?
ETHANOL AS A PREDICTOR OF SOFT SCALD
Sometimes little soft scald without conditioning, especially if stored at 38F, but a prediction method might allow storage at 33F as well!

- But always uncertainty about season and fruit maturity

Fermentation flavor common, and ‘taste sampling’ program is a strong recommendation!
Anaerobic respiration

Pyruvate → acetaldehyde → Ethanol

Normal fruit respiration
Prediction with and without conditioning

Champlain orchard harvested 9/21/13

33F and 38F with and without conditioning

Samples taken during storage for ethanol

Assessed after 4 months plus 7 days at 68F
Ethanol accumulation as an indicator of soft scald? Effect of storage temperature.

33 F

42% soft scald

38 F

0% soft scald
Ethanol accumulation as an indicator of soft scald? Effect of conditioning at 33°F.

33 F

Conditioning and 33 F.

42% soft scald

1% soft scald
Ethanol accumulation as an indicator of soft scald? Effect of conditioning at 38F.

38 F

Conditioning at 38 F.

0% soft scald

0% soft scald
Soft scald 2014

- Project as described before
- 18 orchards in NY, plus 2 PA orchards
- Stored only at 38F!
- Ethanol at intervals
- Soft scald at 10 and 20 weeks
Effects of conditioning on soft scald (%) after 20 weeks of air storage [2014/15]

<table>
<thead>
<tr>
<th></th>
<th>38°F</th>
<th>Cond. + 38°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA1</td>
<td>3.5</td>
<td>0</td>
</tr>
<tr>
<td>PA2</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>HV1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HV2</td>
<td>7.3</td>
<td>0</td>
</tr>
<tr>
<td>HV3</td>
<td>2.2</td>
<td>0</td>
</tr>
<tr>
<td>WNY1</td>
<td>4.2</td>
<td>0</td>
</tr>
<tr>
<td>WNY2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CH1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>CH2</td>
<td>3.9</td>
<td>0</td>
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<tr>
<td>CH3</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td>2.4</td>
<td>0</td>
</tr>
</tbody>
</table>

Overall, low levels
Ethanol - examples

Champlain orchard 1

Champlain orchard 2

mg/kg

Weeks

0 1 2 3 4 5 6 8 10

0 1 2 3 4 5 6 8 10

38F  50 to 38F
To this year!
Regional trial - 2015

- Fruit from 4 PA, 3 HV, 3 WNY, 3 CH orchard blocks
- 33F and 38F with and without conditioning for 20 weeks
- Data – harvest indices, ethanol at 0, 1, 2, 3, 5 and 10 weeks
- Only PA storage results available – completed last week!
<table>
<thead>
<tr>
<th>Orchard</th>
<th>IEC (ppm)</th>
<th>Firmness (lb-f)</th>
<th>SPI (1-8)</th>
<th>I_{AD} values</th>
<th>SSC (%)</th>
<th>Acidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>15.1</td>
<td>6.8</td>
<td>0.47</td>
<td>12.9</td>
<td>0.405</td>
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<tr>
<td>2</td>
<td>14</td>
<td>16.2</td>
<td>7.1</td>
<td>0.35</td>
<td>14.5</td>
<td>0.521</td>
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<td>3</td>
<td>41</td>
<td>14.6</td>
<td>7.7</td>
<td>0.64</td>
<td>13.1</td>
<td>0.415</td>
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<td>4</td>
<td>21</td>
<td>15.6</td>
<td>7.7</td>
<td>0.27</td>
<td>13.3</td>
<td>0.414</td>
</tr>
</tbody>
</table>
PA harvest 2015 - Bitter pit (%)

Orchards

Temperature x conditioning
PA harvest 2015 – Bitter pit (%)
PA harvest 2015 – soft scald and soggy breakdown: only at 33F and trivial levels

Soft scald (%)

Soggy breakdown (%)
Trivial amounts of:
- Senescent breakdown
- CO$_2$ pockets
- ‘Flesh browning’ (moist)

More severe decay at 38F than at 33F

But wrinkly skin
PA harvest 2015 – Skin wrinkling (%) only at 33F (though found at 38F in 2014)

Orchard x Temperature x conditioning
High bitter pit risk.

Lowest soft scald risk, but ‘skin wrinkling/browning’ risk higher.

Should fruit be stored at 33F without conditioning?

- What is risk? Is sporadic soft scald worth having if much larger losses from bitter pit can be alleviated?

Conservative storage temperature would be 38F (and I’d be willing to say without conditioning except where block history of soft scald)

Bitter pit management in orchard #1 defense
Overall conclusion

- Honeycrisp represents the most difficult apple to work with
- A series of adventures, with different issues discovered each year!
- Still don’t have firm answers, only lots of speculation!
- If it wasn’t such a great eating experience it would rate as the world’s most disastrous apple ever bred!
CONTROLLED ATMOSPHERE STORAGE
Until now, major reservations about CA storage of Honeycrisp

- High risk of internal CO$_2$ injury
  - Variable
  - Regional factor – generally worse southern regions

- Limited urgency because of strong effects of 1-MCP on maintaining quality
Champlain: Untrt vs 1-MCP (air) vs CA – 6 months

<table>
<thead>
<tr>
<th></th>
<th>UNTRT</th>
<th>SmartFresh</th>
<th>CA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Firmness (lb-f)</strong></td>
<td>15.5</td>
<td>15.5</td>
<td>15.5</td>
</tr>
<tr>
<td><strong>SSC (%)</strong></td>
<td>12.0</td>
<td>12.4*</td>
<td>12.8***</td>
</tr>
<tr>
<td><strong>TA (%)</strong></td>
<td>0.228</td>
<td>0.267***</td>
<td>0.297***</td>
</tr>
</tbody>
</table>
Orchard variation in susceptibility to CO₂ injury - Orchard variation

<table>
<thead>
<tr>
<th>CA regime (O₂/CO₂)</th>
<th>#2</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5/1.5</td>
<td>3</td>
<td>5</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>3.0/1.5</td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>4.5/1.5</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>2</td>
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<tr>
<td>1.5/3.0</td>
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<td>11</td>
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<td>3.0/3.0</td>
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<tr>
<td>4.5/3.0</td>
<td>16</td>
<td>8</td>
<td>25</td>
<td>6</td>
</tr>
</tbody>
</table>
Internal CO$_2$ injury

Two main potential methods of control

1. DPA

2. Delayed CA
Effects of DPA

- Fruit from 2 orchard blocks in each region - Hudson Valley, WNY and Champlain
- Untreated or treated with DPA at harvest
- No delay, or conditioned at 50°F for 7 days
- CA applied 8 days after harvest
- CA (3% O₂/3% CO₂) at 38°F
- Evaluated after 6 months of storage plus 4 days at 68°F
CO₂ injury (%) after storage
CO$_2$ injury (%) after storage

- 38F
- 38F + DPA
- Cond.
- Cond. + DPA

Legend:
- HV 1
- HV 2
- CH 1
- CH 2
- WNY 1
- WNY 2
Soft scald (%) after storage – 38F

Untrt | DPA | Cond. | Cond. + DPA
--- | --- | --- | ---
HV1 | HV2 | CH1 | CH2 | WNY1 | WNY2
Effects of delayed CA

- Fruit harvested commercially from 5 WNY orchards on 9/19/2013
- Conditioning
- CA of 3%/3% applied after 1, 3 and 5 weeks at 38F
- Evaluated after 6 months plus 4 days at 68F
CO\textsubscript{2} injury (%) after CA (3%/3%) storage - 1, 3 and 5 week delay

Negligible soft scald, little effect on bitter pit, small increase in greasiness.
Quality as judged by firmness, acidity, SSC is not compromised
Effects of delayed CA

- Fruit from 3 orchard blocks in each of Champlain and Western NY
  - Champlain – 9/18
  - WNY – 9/24

- All fruit were conditioned at 50°F for 1 week, with 1-MCP applied 1 or 6 days after harvest.

- Fruit cooled overnight to 38°F and CA applied immediately or after 4 weeks

- CA at 3% oxygen and either 1.5% or 3% carbon dioxide
**CO₂ injury and greasiness in CA stored fruit**  
- CA immediately after conditioning or after 4 weeks at 38F in air

### CO₂ injury (%)

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Champlain</th>
<th>WNY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>4***</td>
<td>5***</td>
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</tbody>
</table>

### Greasiness (%)

<table>
<thead>
<tr>
<th>Weeks</th>
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<th>WNY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>28**</td>
<td>28***</td>
</tr>
</tbody>
</table>
Core browning and flesh firmness in CA stored fruit
- CA immediately after conditioning or after 4 weeks at 38F in air

### Core browning (％)

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Champlain</th>
<th>WNY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>7***</td>
<td>4NS</td>
</tr>
</tbody>
</table>

### Firmness (lb-f)

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Champlain</th>
<th>WNY</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14.7</td>
<td>15.1</td>
</tr>
<tr>
<td>4</td>
<td>14.7&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>15.6&lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

No effects on SSC and acidity
Summary

Delaying CA for 4 weeks after conditioning:

■ Markedly reduces CO$_2$ injury risk.
■ Slightly increases greasiness, though ratings still slight.
■ Small increased risk of core browning.
■ No significant loss of quality – firmness, SSC or titratable acidity.
Overall conclusion

- Probably could avoid CA risk by using 1-MCP with air storage for the foreseeable future.

- If CA storage, conditioning recommended - then two options:
  1. DPA treatment (decay a concern)
  2. Delayed CA – 4 weeks looks pretty good

- CA – 3% oxygen/3% carbon dioxide at 38F.
THANK YOU! QUESTIONS?