Grower Summary

TF 192

Modulating the storage temperature for Cox apples for improved quality and control of rotting (Years 1-2)

Modulating the storage temperature for Braeburn apples for improved quality (Year 3)

Final 2012

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.

Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

Further information

If you would like a copy of the full report, please email the HDC office (hdc@hdc.ahdb.org.uk), quoting your HDC number, alternatively contact the HDC at the address below.

HDC
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

Tel – 0247 669 2051

HDC is a division of the Agriculture and Horticulture Development Board.

Project Number:	TF 192
Project Title:	Modulating the storage temperature for Cox apples for improved quality and control of rotting (Years 1-2) Modulating the storage temperature for Braeburn apples for improved quality (Year 3)
Project Leader:	Dr Angela Berrie
Contractor:	East Malling Research
Industry Representative:	Nigel Jenner
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Start Date:	01 July 2009
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Project Cost:	£54,040

Headline

Modulating storage temperatures of Cox and Braeburn below the current recommendations does not improve fruit quality.

Background and expected deliverables

Cox (Project Years 1-2)

Cox remains the most important dessert apple variety in the UK, despite its susceptibility to a range of physiological disorders and fungal rots. The firmness of the stored fruit at the point of sale is often marginal in relation to specifications laid down by the multiple retailers, despite harvesting at the correct stage of maturity and providing optimum storage conditions. Although the use of 1-MCP (SmartFresh^{TM}) has helped significantly to delay softening during storage and shelf-life, care must be taken when it is used on fruit destined for post-January storage due to a heightened risk of core flush. This project addresses the need to supply consumers with Cox of consistent quality from September until March, and to minimise the wastage incurred by growers due to the development of fungal rots.

Current levels of wastage are often unacceptable and there is limited scope for chemical intervention to ameliorate the problem, although use of rot risk assessment can assist in management of rots and minimize losses. There are currently no fungicides permitted for post-harvest application to apples in the UK. Fungicides applied pre-harvest for rot control usually result in detectable residues in the fruit at harvest and are still present after cold storage.

Reducing the temperature for Controlled Atmosphere (CA)-stored Cox provides an opportunity to improve fruit quality, particularly firmness, and to reduce rot development. However, it is imperative that these benefits are achieved without inducing low temperature breakdown (LTB) symptoms in the fruit. Although climate change means that there is a greater likelihood of warmer growing seasons in the future and consequently a reduced susceptibility to LTB, it is unlikely that Cox will tolerate a lower storage temperature for the entire storage period. However, modulating the store temperature to provide shorter periods at lower temperatures may provide the benefits required without inducing LTB in the fruit. This approach has proved successful for other chilling-sensitive varieties in work done abroad (such as cv. McIntosh in Canada). The objective of this project was to develop a strategy for modified temperature management of commercial Cox stores in the UK that would include the use of 1-MCP (SmartFresh^{TM}).

Braeburn (Project Year 3)

With increasing volumes of Braeburn being planted, there is a need to extend the storage life of fruit to modulate the supply of fruit onto the UK market. Braeburn is a variety that maintains good texture and eating quality, but storage is often storage terminated prematurely because of internal physiological disorders. The high density of Braeburn apples gives rise to poor gas diffusion properties leading to the accumulation of internal CO_2 and depletion of oxygen (hypoxia). Establishing CA conditions too rapidly can lead to symptoms of flesh browning early in the storage season, referred to as Braeburn Browning Disorder (BBD). A second distinct condition known as late-season core-flush is associated with a pink/brown discolouration of the flesh surrounding the core cavity and its severity increases with the length of CA storage. Harvesting over-mature fruit, establishing CA conditions too rapidly or storing at too low a temperature for prolonged periods can exacerbate the condition.

However, introduction of shorter periods of intermittent low-temperature (0.5-1.0°C) or delayed ethylene scrubbing into a standard CA Braeburn regime (1.2% $O_{2,}$ <1% CO_2 at 1.5-2.0°C) may help to reduce the overall respiration rate of fruit, preventing a localised depletion of oxygen in the core region that often leads to damage. The objective of this project was to investigate the use of modulated storage temperatures or delayed ethylene scrubbing during CA storage of Braeburn to improve fruit quality and possibly extend the storage life of Braeburn.

Summary of the project and main conclusions

Cox (Year 1)

Cox apples were harvested on 2 September 2009 from an 11 year-old Cox orchard planted on M9 rootstock. Maturity measurements (Firmness, Colour, Starch, % Brix and internal ethylene concentration) were made on the day of harvest. Apples were cooled to 3.5°C overnight.

The day following harvest, half the fruits were treated with SmartFresh^{TM} (625 ppb) at 3.5°C for 24 hours whilst the untreated fruit were kept in a separate store at 3.5°C.
Subsequently, half of the SmartFresh^{TM}-treated and untreated fruit were inoculated with *Nectria*. This provided a total of four post-harvest treatment combinations: untreated/uninoculated, SmartFresh^{TM}/uninoculated, untreated/*Nectria* and SmartFresh^{TM}/*Nectria.*

Four boxes each containing one of the treatment combinations were loaded into each of eight storage cabinets and flushed with nitrogen to 1.25% O_2. Four cabinets were maintained at 3.5°C and four at 1.5°C. Every two months, the fruit were moved between cabinets at the two temperatures so that eight temperature regimes were tested, as shown in Table 1.

Table 1. Temperature regimes assessed during the Cox storage trials

Treatment	**0 – 60 days**	**60 – 120 days**	**120 – 180 days**
1	3.5-4^{o}C	3.5-4^{o}C	3.5-4^{o}C
2	1.5-2^{o}C	3.5-4^{o}C	3.5-4^{o}C
3	1.5-2^{o}C	1.5-2^{o}C	3.5-4^{o}C
4	1.5-2^{o}C	1.5-2^{o}C	1.5-2^{o}C
5	3.5-4^{o}C	1.5-2^{o}C	3.5-4^{o}C
6	3.5-4^{o}C	1.5-2^{o}C	1.5-2^{o}C
7	1.5-2^{o}C	3.5-4^{o}C	1.5-2^{o}C
8	3.5-4^{o}C	3.5-4^{o}C	1.5-2^{o}C

Fruits were inspected ex-store and after 1 week's shelf-life at 20°C in November, January and March.

Continuous low temperature storage reduced the rate of softening but caused significant amounts (30%) of LTB in long-term stored Cox. The incidence of LTB increased to 60% when continuous low temperature storage was used on SmartFresh™-treated fruit. Shorter periods of low-temperature used at the beginning of the storage period had a small effect on reducing the degree of softening and did not induce LTB in non-SmartFresh™-treated fruit. LTB was observed on SmartFresh™-treated Cox but was less severe than found in continuous low temperature storage.

The incidence of *Nectria* rots was reduced with SmartFresh™ when combined with storage at 1.5°C. SmartFresh™-treated Cox that received at least 4 months at 1.5°C had less rots. Interestingly, SmartFresh™ did not affect the incidence of rotting when Cox was stored at 3.5°C for the whole period. Rotting in untreated Cox was more variable and no clear trend in temperature regime was evident; however, fruit stored for the whole storage period at 1.5°C had the lowest incidence of rots.

Cox (Year 2)

Cox apples were harvested on three occasions: 6, 13 and 20 September 2010 from a 12 year-old Cox orchard planted on M.9 rootstock. Maturity measurements (Firmness, Colour, Starch, % Brix and internal ethylene concentration) were made on the day of harvest. Apples were cooled to 3.5°C overnight.

After cooling fruit to store temperature, half the fruit was treated with SmartFresh™ (625 ppb) at 3.5°C for 24 hours whilst the untreated fruit were kept in a separate store at 3.5°C.

Subsequently, half of the SmartFresh™-treated and untreated fruit were inoculated with *Nectria*. This provided a total of four post-harvest treatment combinations: untreated/uninoculated, SmartFresh™/uninoculated, untreated/*Nectria* and SmartFresh™/*Nectria.*

Two replicate cabinets were used for each temperature combination. A box of SmartFresh™-treated and untreated Cox from each pick were placed in each cabinet. In addition, netted samples of inoculated fruit were added to each cabinet. After loading, cabinets were flushed with nitrogen to 1.25% O_2. During the initial two month storage period six cabinets were maintained at 3.5°C and four at 1.5°C. Every two months, fruit was moved between cabinets at the two temperatures so that five most promising temperature regimes from year 1 were tested in year 2. These are detailed as Table 2.

Table 2. Temperature regimes assessed during the Cox storage trials

Treatment	**0 – 60 days**	**60 – 120 days**	**120 – 180 days**
1	3.5-4°C	3.5-4°C	3.5-4°C
2	3.5-4°C	3.5-4°C	1.5-2°C
3	3.5-4°C	1.5-2°C	1.5-2°C
6	1.5-2°C	1.5-2°C	3.5-4°C
7	1.5-2°C	3.5-4°C	3.5-4°C

Cox were inspected ex-store in November, January and March. Additional assessments were made after 1 week's shelf-life at 18°C following each inspection.

The 2010/11 season was not a high risk year for LTB or core flush in Cox. Consequently no symptoms of either disorder appeared in Cox during periods of low-temperature storage. No benefit of improved firmness retention was accrued by incorporating periods of low-temperature storage. Extending the length of storage at low temperature to 4 months out of 6 increased physiological stress. Although no internal physiological disorders were visible, sub-clinical damage caused by prolonged exposure to low-temperatures resulted in elevated respiration rates leading to greater rates of fruit softening. SmartFresh^{TM}-treated fruit remained firm throughout the 6-month storage period and although late picked fruit (pick 3) were marginally softer, SmartFresh^{TM} treatments maintained firmness retention above commercial threshold of acceptable firmness. Non-treated Cox harvested from picks 1 and 2 and stored under standard 3.5°C temperature condition maintained firmness above 65 N for the full six months storage period. Pick 3 fruit only lasted 60 days before firmness values dropped below 65 N.

Reducing storage temperatures to 1.5°C earlier in the storage life reduced the incidence of *Nectria* rots, while lowering storage temperatures between January and March had less impact on rot development.

In conclusion, low-temperature storage was able to reduce the incidence of *Nectria* rotting, however, the heightened risk of internal damage, precluded this treatment as a practical method of rot control.

SmartFresh^{TM} was able to improve firmness retention during storage and was particularly effective on early picked fruit. Delaying the harvest date led to a progressive loss of firmness during storage in untreated fruit. However, firmness retention was improved in late picked fruit by the application of SmartFresh^{TM} at harvest. Low-temperature storage was not a suitable alternative to Smartfresh^{TM} in maintaining fruit quality during extended storage.

Braeburn (Year 3)

Braeburn apples from six orchards, comprising four Hilwell and two Lochbuie clones were picked on the week beginning 4 October. Storage samples were cooled for 48 hours, before a holding CA of 2% O_2 was established by respiration and maintained for 10 days. The final storage CA regime of 1.2% O_2 was then established through fruit respiration. Fruit was subject to periods of modulated temperature (Table 3) each lasting 70 days of either a standard (1.5-2°C) or low temperature regime (0.5-1.0°C). Delayed ethylene scrubbing was applied by placing5 kg bags of potassium permanganate coated clay beads into selected cabinets after the first 70 days of storage.

Braeburn was harvested at the optimum commercial maturity, when fruit background red colour had reached 50% coverage with 80% starch content. However, considerable variation in physiological maturity was observed within the 6 orchard sites. Internal ethylene exhibited a range from 77 ppb to 538 ppb and starch clearance patterns ranged from 3-5 on the CTIFL scale. Moreover, fruit respiration varied from 5.3-7.4 ml CO_2 kg^{-1} h^{-1}. Fruit sugar content (% Brix) was related to the dry matter content of fruit at harvest rather than related to fruit maturity. The range of maturities of fruit at harvest was reflected in the quality of fruit during storage.

Table 3. Temperature regimes assessed during the Braeburn storage trials 2011-2012

Treatment	0 – 70 days	70 – 140 days	140 – 210 days
1	1.5-2°C	1.5-2°C	1.5-2°C
2	1.5-2°C	1.5-2°C	0.5-1°C
3	1.5-2°C	0.5-1°C	0.5-1°C
4	0.5-1°C	1.5-2°C	1.5-2°C
5	0.5-1°C	0.5-1°C	1.5-2°C
6	0.5-1°C	0.5-1°C	0.5-1°C
7*	1.5-2°C	1.5-2°C	1.5-2°C
8*	0.5-1°C	0.5-1°C	0.5-1°C

* Delayed ethylene scrubbing after 70 days

Orchards that were more mature at harvest were prone to developing core-flush and Braeburn Browning Disorder (BBD). Fruit with respiration rates above 6 ml CO_2 kg^{-1} h^{-1} resulted in a greater incidence of internal disorders.

Fruit firmness remained high (70-90 N) in all orchard consignments after 7 months storage and only limited softening was evident after shelf-life conditioning. Storage at lower temperatures had little influence on firmness, retention of green background or the incidence of internal physiological disorders. Fruits subjected to lower temperature (0.5-1.0°C) storage at the beginning of the storage season were under greater physiological stress leading to higher concentrations of ethylene in the storage atmosphere.

The addition of delayed ethylene scrubbing reduced the loss of background green colour that occurred late in the storage season in orchard consignments that were over mature entering storage. The effect of ethylene scrubbing on controlling core-flush and Braeburn Browning Disorder was undetermined due to the large variation in the incidence between orchard consignments and treatment effects.

Conclusions

Incorporating periods of lower temperature (1.5-2.0°C) into the standard 6 month storage period for Cox's Orange Pippin reduced the incidence of *Nectria* rots. However, improvements in fruit quality were limited and modulating the temperature did not reduce the risk of low temperature breakdown (LTB).

Modulated low temperature storage (0.5-1.0°C) of Braeburn reduced the rate of softening in fruit from some orchard consignments, but failed to control the development of internal disorders.

Financial benefits

No financial benefits were identified from this research project.

Action points for growers

- Modulating storage temperatures of Cox and Braeburn below current recommendations does not improve fruit quality.

- Harvesting fruit at optimum harvest maturity is critical for maintaining fruit quality during long-term storage. With Braeburn, the standard practice of waiting for fruit to reach 50% red colour can result in harvesting fruit of sub-optimum harvest quality that has a greater potential of developing late-season core-flush and Braeburn Browning Disorder.

- Better indicators of harvest maturity for late season varieties such as Braeburn are needed.