Advanced Postharvest Handling and Storage Technology for Canadian Apples

(2012-13 Season, Year 3)

Dr. Jennifer DeEll

Ontario Ministry of Agriculture and Food
Ministry of Rural Affairs
1283 Blueline Rd. at Hwy #3, Simcoe, ON
E-mail: Jennifer.DeEll@ontario.ca

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Final Project Summary – GF1

(Summary of 3 Years)

Objective 1:
To determine the time frame of flesh browning development (in 'McIntosh' and 'Empire') during CA storage, in relation to growing season and weather data

- Weather data were collected from the apple growing regions in Ontario and Quebec, and relationships between weather during the growing season and disorder development during storage are currently being studied (continuing with Gaétan Bourgeois via GF2).
- It is often 8-9 months in CA storage before flesh browning becomes a major issue.
- Harvest maturity is a major factor in the incidence of flesh browning (more mature, higher incidence).
- Core browning in 'McIntosh' was more prevalent after 7 days at room temperature, suggesting it was senescent-related browning.
- 'Empire' exhibited more external CO_2 injury than 'McIntosh' at all storage removals and incidence was often augmented by SmartFresh.
- SmartFresh had inconsistent effects on flesh and core browning incidence in 'Empire'.

Objective 2:
To evaluate the effects of postharvest handling, 1-MCP technology, and storage regimes on the physical and sensory quality of new apple cultivars

'Honeycrisp'

- All conditioning treatments (delayed cooling), regardless of temperature (10 or 20^{o}C) or duration, substantially reduced the incidence of soft scald.
- Conditioning at higher than 10^{o}C or for more than 7 days increased ethylene production, shrivel, greasiness, and bitter pit, as well as reduced acidity.
- Treatment with SmartFresh resulted in less peel greasiness, lower internal ethylene concentration, greater malic acid content, and higher soluble solids concentration.
- SmartFresh had inconsistent effects on soft scald incidence and bitter pit was sometimes exacerbated.
- CA storage resulted in less peel greasiness and often lower soft scald incidence (1-8%).
- Internal CO_2 injury (0-34%) was aggravated by CA and SmartFresh.
- Senescent browning (8-23%) was reduced by SmartFresh in CA storage.

- SmartFresh-treated ‘Honeycrisp’ had lower perceived intensities of *oxidized red apple* and *earthy* flavors, less perceived *skin thickness* and *chewy* textures, and higher *lemony*, *fresh green apple* and *acid* ratings.
- Without SmartFresh, ‘Honeycrisp’ stored in air had higher perceived *oxidized red apple* and *earthy* flavors and less perceived intensity of *acid* taste than those in CA.

‘Creston’

- CA storage (2.5% O_2 + 2.5% CO_2) at 0-1^{o}C for 6 months inhibited ethylene production (<1 ppm), retained fruit firmness and acidity, controlled greasiness development, and reduced storage rots.
- SmartFresh delayed softening, e.g. after 2 months in air storage at 0^{o}C plus 7 days at ~20^{o}C, firmness values were similar to those at harvest.
- SmartFresh-treated apples had substantially less ethylene and greater acidity.
- Storage rots developed after 6 months, but rot incidence was reduced by SmartFresh.
- Bitter pit developed in all years of study and the lesions can be exacerbated by SmartFresh.

‘Nicola’

- Tends to be very susceptible to russet and lenticel damage, which influences fruit quality during storage.
- SmartFresh resulted in substantially less internal ethylene and greater firmness and acidity after 2- 4 months of air storage at 0^{o}C.
- Few disorders were found and firmness was maintained (~harvest values) during 6 months of CA storage (2.5% O_2 + 2.5% CO_2) at 0-1^{o}C.

Objective 3:
To investigate the application of diphenylamine using aerosol or thermo-fogging technology in commercial apple storage rooms

- Decco DPA Aerosol received Canadian registration in August 2011.
- Pace EcoFog 100 (DPA) received Canadian registration in June 2012.

Year 3 Results, 2012-13 Season

Flesh Browning in 'Empire' and 'McIntosh' Apples

Objective 1: To determine the time frame of flesh browning development during CA storage, in relation to growing season and weather data.

Flesh browning and related low temperature (chilling) disorders are ongoing concerns for the Canadian apple industry.

'Empire' and 'McIntosh' apples were harvested from commercial orchards in Simcoe, Ontario and Frelighsburg, Quebec. Apples from Ontario were transported to the *Apple Research Storage Lab* in Simcoe, Ontario within one hour of harvest. Fruit from Quebec were sent via refrigerated truck on the same day as harvest.

Harvest dates and fruit maturity upon arrival at the lab are presented in Table 1.

Table 1: Harvest date and maturity of 'McIntosh' and 'Empire' apples from Ontario and Quebec.

	Date	Blush (%)	Internal ethylene (ppm)	Firmness (lb-force)	Soluble solids (%)	Malic acid (mg/100 ml)	Starch index (1-8)
Ontario							
McIntosh	Aug. 31	38	0	16.4	11.2	1140	5.2
Empire	Sept. 20	60	0.5	16.4	11.6	838	4.2
Quebec							
McIntosh	Sept. 20	75	58	14.8	11.9	805	6.1
Empire	Oct. 5	73	10	15.1	12.2	738	5.5

Upon arrival, fruit were cooled overnight to 3°C. Half of the apples were then treated with SmartFresh (1 ppm, 1-MCP) for 24 hours. All apples were stored for 10 months in standard controlled atmosphere (CA) at 3°C. 'McIntosh' apples were held in 2.5% O_2 + 2.5% CO_2 for 1 month, 3.5% CO_2 for the second month, followed by 4.5% CO_2 thereafter. 'Empire' fruit were constantly held in 2.5% O_2 + 2.0% CO_2. After 5 months of storage, one bushel box per treatment from each location was removed for fruit quality evaluations. The results for 'McIntosh' and 'Empire' are presented in Tables 2 and 3, respectively.

It is important to note that fruit from Ontario was of poor quality this season due to several severe spring frost events. There was >80% crop loss and the fruit that survived did not receive the typical amount of orchard sprays throughout the growing season. As a result, the Ontario 'McIntosh' and 'Empire' were not from the same orchard blocks as in past years of this study (but were from the same grower).

As expected, SmartFresh treatment significantly improved firmness retention and reduced ethylene production in 'McIntosh' and 'Empire' apples. There was also an apparent effect on titratable acidity, with often higher malic acid content in SmartFresh-treated fruit. However, this effect was not consistent in 'Empire', as SmartFresh-treated 'Empire' sometimes had lower malic acid content than those not treated.

Substantial external CO_2 injury developed in Ontario 'McIntosh' (Plate 1), as well as in both Ontario and Quebec 'Empire' (Plate 2). The disorder was present at all storage removals and incidence was often augmented by SmartFresh. It is important to note that none of the apples used in this experiment had been treated with diphenylamine (DPA).

A small incidence of internal CO_2 injury (<5%) was also found in 'McIntosh' after 7 months of storage (Plate 3). This appeared in both Ontario and Quebec 'McIntosh' and SmartFresh had no significant effect (data not presented).

There was little senescent breakdown or core browning in 'McIntosh' until 9 months of storage (Plates 4 and 5). These disorders were more prevalent after 7 days at room temperature, suggesting it was senescent-related browning. This is similar to observations in the previous year of study.

After 7 and 8 months of storage, 'Empire' began exhibiting flesh and core browning, respectively (Plate 6). SmartFresh often increased the incidence of these disorders, especially in Quebec 'Empire' where the incidence was much higher than in those from Ontario. Inconsistent effects of SmartFresh on these disorders were observed in the previous two years of study.

Weather data were collected from the apple growing regions in Ontario and Quebec, and relationships between weather during the growing season and disorder development during storage are currently underway. This research will also be continuing within the Canadian Agri-Science Cluster for Horticulture, Growing Forward 2.

Plate 1: External CO_2 injury in ‘McIntosh’ after 7 months of CA storage.

Plate 2: External CO_2 injury in ‘Empire’ after 8 months of CA storage.

Plate 3: Internal CO_2 injury in ‘McIntosh’ after 7 months of CA storage.

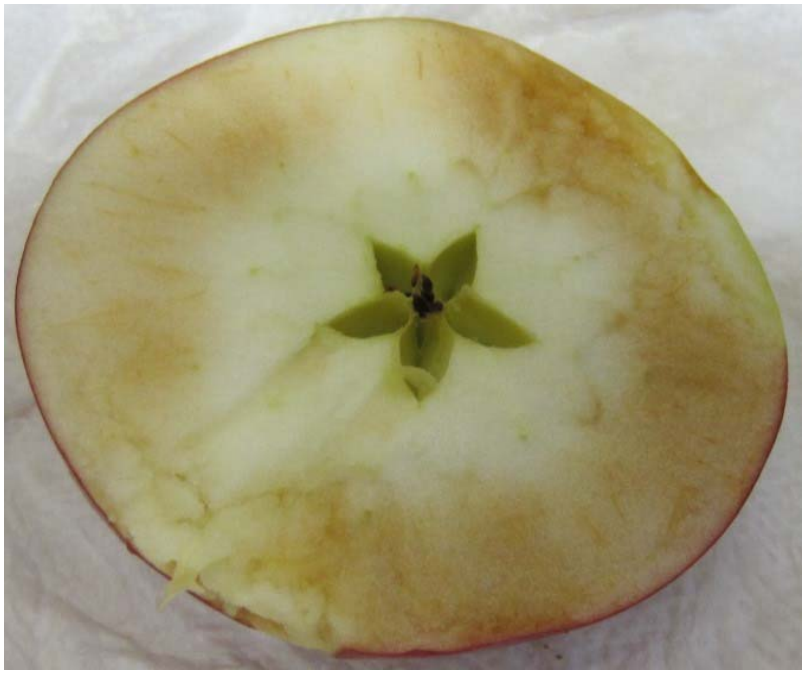

Plate 4: Senescent breakdown in ‘McIntosh’ after 9 months of CA storage.

Plate 5: Core browning in ‘McIntosh’ after 9 months of CA storage.

Plate 6: Core browning in ‘Empire’ after 8 months of CA storage.

Table 2: Quality and disorders of 'McIntosh' apples treated with or without SmartFresh and stored for 5 to 10 months in CA (2.5% O_2 + 2.5 / 4.5% CO_2) at 3°C, plus 1 or 7 days at room temperature (RT, ~18-22°C).

	Firmness (lb-force)	Internal ethylene (ppm)	Soluble solids (%)	Malic acid (mg/100 ml)	External CO_2 injury (%)	Senescent breakdown (%)	Core browning (%)	Storage rots (%)
5 months CA								
1 Day at RT								
Ontario								
Control	13.9 ^{C}	138 ^{CD}	12.8 ^{A}	855 ^{A}	40.0 ^{B}	0	0	3.3 ^{B}
SmartFresh	16.6 ^{B}	2 ^{E}	13.3 ^{A}	916 ^{A}	53.3 ^{A}	0	0	0 ^{B}
Quebec								
Control	12.8 ^{D}	161 ^{C}	11.6 ^{C}	495 ^{C}	0 ^{C}	0	0	3.3 ^{B}
SmartFresh	14.5 ^{C}	26 ^{DE}	12.2 ^{B}	593 ^{B}	0 ^{C}	0	0	0 ^{B}
7 Days at RT								
Ontario								
Control	12.0 ^{E}	589 ^{B}	13.0 ^{A}	880 ^{A}	31.4 ^{B}	0	0	11.4 ^{A}
SmartFresh	17.5 ^{A}	4 ^{E}	13.0 ^{A}	880 ^{A}	63.5 ^{A}	0	0	5.8 ^{AB}
Quebec								
Control	10.1 ^{F}	782 ^{A}	11.7 ^{BC}	494 ^{C}	0 ^{C}	0	0	0 ^{B}
SmartFresh	14.3 ^{C}	138 ^{CD}	12.2 ^{B}	601 ^{B}	2.7 ^{C}	0	0	0 ^{B}
Significance[1]	****	****	****	****	****			**
6 months CA								
1 Day at RT								
Ontario								
Control	13.3 ^{D}	154 ^{BC}	13.2 ^{AB}	796 ^{B}	40.0 ^{AB}	0	0	11.1 ^{A}
SmartFresh	16.8 ^{A}	30 ^{C}	13.9 ^{A}	917 ^{A}	26.7 ^{B}	0	0	13.3 ^{A}

Quebec								
Control	12.3 ^{E}	162 ^{BC}	11.4 ^{D}	464 ^{E}	0 ^{C}	0	0	0 ^{B}
SmartFresh	14.4 ^{C}	11 ^{C}	12.5 ^{BC}	601 ^{D}	8.9 ^{C}	0	0	0 ^{B}
7 Days at RT								
Ontario								
Control	11.0 ^{F}	733 ^{A}	12.2 ^{CD}	689 ^{C}	30.1 ^{AB}	0	0	2.7 ^{B}
SmartFresh	16.0 ^{B}	27 ^{C}	12.5 ^{BC}	907 ^{A}	41.7 ^{A}	0	0	2.8 ^{B}
Quebec								
Control	10.3 ^{F}	761 ^{A}	11.7 ^{CD}	466 ^{E}	0 ^{C}	0	0	0 ^{B}
SmartFresh	14.3 ^{C}	273 ^{B}	12.1 ^{CD}	506 ^{E}	5.4 ^{C}	0	0	3.3 ^{B}
Significance	****	****	**	****	****			***
7 months CA								
1 Day at RT								
Ontario								
Control	11.8 ^{E}	236 ^{C}	13.3 ^{A}	809 ^{A}	20.0 ^{C}	0	0	0 ^{B}
SmartFresh	15.6 ^{B}	6 ^{D}	13.2 ^{AB}	799 ^{A}	62.2 ^{A}	0	0	6.7 ^{B}
Quebec								
Control	13.2 ^{D}	227 ^{C}	11.5 ^{E}	431 ^{CD}	2.2 ^{D}	0	0	0 ^{B}
SmartFresh	14.8 ^{BC}	12 ^{D}	12.0 ^{D}	487 ^{C}	2.2 ^{D}	0	0	0 ^{B}
7 Days at RT								
Ontario								
Control	11.2 ^{E}	766 ^{B}	12.9 ^{B}	647 ^{B}	10.0 ^{CD}	0	0	0 ^{B}
SmartFresh	17.1 ^{A}	67 ^{D}	12.5 ^{C}	757 ^{A}	40.3 ^{B}	0	0	28.4 ^{A}
Quebec								
Control	10.0 ^{F}	995 ^{A}	11.3 ^{E}	392 ^{D}	0 ^{D}	0	0	0 ^{B}
SmartFresh	14.6 ^{C}	250 ^{C}	11.8 ^{D}	484 ^{C}	0 ^{D}	0	0	0 ^{B}
Significance	****	****	****	****	****			****

8 months CA								
1 Day at RT								
Ontario								
Control	12.2 ^{D}	233 ^{CD}	13.2 ^{AB}	750 ^{A}	26.7 ^{C}	0	0	0 ^{C}
SmartFresh	15.5 ^{A}	4 ^{E}	13.2 ^{AB}	758 ^{A}	53.3 ^{B}	0	0	8.9 ^{C}
Quebec								
Control	11.5 ^{D}	214 ^{D}	11.7 ^{C}	422 ^{BC}	0 ^{D}	0	0	0 ^{C}
SmartFresh	14.8 ^{A}	52 ^{E}	11.8 ^{C}	450 ^{B}	0 ^{D}	0	0	0 ^{C}
7 Days at RT								
Ontario								
Control	10.0 ^{E}	867 ^{B}	13.2 ^{B}	705 ^{A}	25.7 ^{C}	0	0	18.6 ^{B}
SmartFresh	13.9 ^{B}	228 ^{CD}	13.9 ^{A}	712 ^{A}	85.7 ^{A}	0	0	52.4 ^{A}
Quebec								
Control	9.4 ^{E}	1244 ^{A}	11.5 ^{C}	360 ^{C}	1.1 ^{D}	0	0	2.2 ^{C}
SmartFresh	13.2 ^{C}	383 ^{C}	11.6 ^{C}	444 ^{B}	2.9 ^{D}	0	0	1.0 ^{C}
Significance	****	****	****	****	****			****
9 months CA								
1 Day at RT								
Ontario								
Control	11.6 ^{D}	273 ^{D}	12.6 ^{AB}	683 ^{A}	11.1 ^{DE}	0 ^{B}	0 ^{A}	0 ^{B}
SmartFresh	16.2 ^{A}	3 ^{E}	13.1 ^{A}	586 ^{A}	35.6 ^{B}	0 ^{B}	0 ^{A}	4.4 ^{B}
Quebec								
Control	11.0 ^{DE}	235 ^{D}	12.1 ^{BC}	556 ^{A}	20.0 ^{CD}	0 ^{B}	0 ^{A}	2.2 ^{B}
SmartFresh	14.2 ^{B}	37 ^{E}	11.5 ^{C}	408 ^{A}	0 ^{E}	0 ^{B}	0 ^{A}	0 ^{B}

7 Days at RT								
Ontario								
Control	10.3 ^{E}	982 ^{B}	11.7 ^{C}	459 ^{A}	24.1 ^{C}	3.6 ^{AB}	1.2 ^{A}	8.4 ^{B}
SmartFresh	13.2 ^{C}	347 ^{D}	12.8 ^{A}	666 ^{A}	75.4 ^{A}	3.3 ^{AB}	0 ^{A}	63.9 ^{A}
Quebec								
Control	8.7 ^{F}	1351 ^{A}	11.7 ^{C}	393 ^{A}	0 ^{E}	3.4 ^{AB}	4.6 ^{A}	1.1 ^{B}
SmartFresh	11.8 ^{D}	771 ^{C}	12.0 ^{BC}	391 ^{A}	0 ^{E}	7.4 ^{A}	1.1 ^{A}	4.2 ^{B}
Significance	****	****	*	NS	***	*	NS	****
<u>10 months CA</u>								
1 Day at RT								
Ontario								
Control	10.7 ^{CD}	386 ^{C}	12.9 ^{A}	577 ^{B}	37.8 ^{B}	0 ^{B}	11.1 ^{A}	0 ^{C}
SmartFresh	16.3 ^{A}	24 ^{D}	12.4 ^{B}	629 ^{A}	55.6 ^{A}	0 ^{B}	2.2 ^{B}	0 ^{C}
Quebec								
Control	11.1 ^{C}	217 ^{CD}	11.6 ^{C}	335 ^{DE}	0 ^{C}	0 ^{B}	0 ^{B}	0 ^{C}
SmartFresh	14.6 ^{B}	30 ^{D}	11.3 ^{C}	374 ^{D}	0 ^{C}	0 ^{B}	0 ^{B}	0 ^{C}
7 Days at RT								
Ontario								
Control	10.1 ^{D}	1325 ^{A}	12.8 ^{A}	538 ^{C}	46.3 ^{AB}	3.0 ^{AB}	0 ^{B}	37.3 ^{B}
SmartFresh	11.3 ^{C}	744 ^{B}	12.6 ^{AB}	587 ^{B}	50.0 ^{AB}	0 ^{B}	0 ^{B}	63.9 ^{A}
Quebec								
Control								
SmartFresh	9.0 ^{E}	1366 ^{A}	11.5 ^{C}	322 ^{E}	0 ^{C}	8.7 ^{A}	5.4 ^{AB}	1.1 ^{C}
	10.4 ^{D}	831 ^{B}	11.8 ^{C}	361 ^{DE}	0 ^{C}	7.2 ^{AB}	7.2 ^{AB}	5.2 ^{C}
Significance								
	****	****	****	****	****	**	**	****

[1] Means within the same column for a given time with the same letter are not significantly different at $P < 0.05$. NS, *, **, ***, **** = not significant, and significant at $P < 0.05$, $P < 0.01$, $P < 0.001$, or $P < 0.0001$, respectively. Each value represents the average of 15 apples for ethylene, 45 and 75 (minimum) for disorders on Day 1 and 7, respectively, and 30 for other indices.

Table 3: Quality and disorders of 'Empire' apples treated with or without SmartFresh and stored for 5 to 10 months in CA (2.5% O_2 + 2.0% CO_2) at 3°C, plus 1 or 7 days at room temperature (RT, ~18-22°C).

	Firmness (lb-force)	Internal ethylene (ppm)	Soluble solids (%)	Malic acid (mg/100 ml)	External CO_2 injury (%)	Flesh browning (%)	Core browning (%)	Storage rots (%)
5 months CA								
1 Day at RT								
Ontario								
Control	15.8 ^{B}	8 ^{C}	12.7 ^{AB}	638 ^{A}	4.4 ^{C}	0	0	2.2 ^{A}
SmartFresh	16.6 ^{A}	0 ^{C}	12.2 $^{A-C}$	577 ^{B}	20.0 ^{B}	0	0	4.4 ^{A}
Quebec								
Control	13.2 ^{D}	31 ^{C}	12.3 $^{A-C}$	488 ^{C}	2.2 ^{C}	0	0	4.4 ^{A}
SmartFresh	15.0 ^{C}	0.2 ^{C}	11.8 ^{BC}	479 ^{C}	34.8 ^{A}	0	0	0 ^{A}
7 Days at RT								
Ontario								
Control	14.6 ^{C}	224 ^{B}	12.5 ^{AB}	590 ^{B}	9.3 ^{BC}	0	0	5.3 ^{A}
SmartFresh	16.2 ^{AB}	4 ^{C}	13.0 ^{A}	649 ^{A}	12.0 ^{BC}	0	0	1.3 ^{A}
Quebec								
Control	11.5 ^{E}	329 ^{A}	11.9 ^{BC}	504 ^{C}	7.0 ^{C}	0	0	1.2 ^{A}
SmartFresh	14.9 ^{C}	3 ^{C}	11.4 ^{C}	515 ^{C}	34.2 ^{A}	0	0	2.7 ^{A}
Significance[1]	****	****	*	****	****			NS
6 months CA								
1 Day at RT								
Ontario								
Control	15.7 ^{C}	24 ^{D}	12.6 $^{A-C}$	563 ^{A}	6.7 ^{C}	0	0	0 ^{B}
SmartFresh	16.6 ^{A}	0.9 ^{D}	13.1 ^{A}	385 ^{C}	0 ^{C}	0	0	0 ^{B}

Quebec								
Control	12.3 ^{G}	102 ^{C}	10.9 ^{E}	398 ^{C}	8.9 ^{BC}	0	0	0 ^{B}
SmartFresh	14.6 ^{E}	0.4 ^{D}	12.1 ^{CD}	474 ^{B}	22.2 ^{AB}	0	0	2.2 ^{B}
7 Days at RT								
Ontario								
Control	13.3 ^{F}	291 ^{B}	12.9 $^{A-C}$	554 ^{A}	9.2 ^{BC}	0	0	4.6 ^{B}
SmartFresh	16.2 ^{B}	2 ^{D}	13.0 ^{AB}	581 ^{A}	21.3 ^{AB}	0	0	4.0 ^{B}
Quebec								
Control	11.6 ^{H}	464 ^{A}	11.3 ^{DE}	385 ^{C}	7.3 ^{C}	0	0	16.7 ^{A}
SmartFresh	15.2 ^{D}	19 ^{D}	12.1 $^{B-D}$	444 ^{B}	30.7 ^{A}	0	0	5.9 ^{B}
Significance	****	****	***	****	****			****
7 months CA								
1 Day at RT								
Ontario								
Control	14.4 ^{C}	23 ^{C}	12.5 ^{A}	572 ^{A}	11.1 $^{A-C}$	0 ^{A}	0	2.2 ^{C}
SmartFresh	15.9 ^{A}	2 ^{C}	12.4 ^{A}	584 ^{A}	8.9 $^{A-C}$	0 ^{A}	0	4.4 ^{BC}
Quebec								
Control	11.5 ^{D}	61 ^{B}	11.5 ^{A}	354 ^{E}	0 ^{C}	0 ^{A}	0	0 ^{C}
SmartFresh	14.5 ^{C}	2 ^{C}	11.7 ^{A}	430 ^{CD}	17.8 ^{AB}	0 ^{A}	0	8.9 ^{BC}
7 Days at RT								
Ontario								
Control	11.6 ^{D}	313 ^{A}	12.2 ^{A}	478 ^{BC}	5.8 ^{BC}	2.9 ^{A}	0	2.9 ^{C}
SmartFresh	16.1 ^{A}	20 ^{C}	11.7 ^{A}	494 ^{B}	21.4 ^{A}	0 ^{A}	0	7.1 ^{BC}
Quebec								
Control	11.1 ^{D}	281 ^{A}	11.8 ^{A}	333 ^{E}	2.4 ^{C}	2.4 ^{A}	0	15.3 ^{B}
SmartFresh	15.4 ^{B}	86 ^{B}	11.6 ^{A}	385 ^{DE}	18.3 ^{AB}	4.9 ^{A}	0	28.0 ^{A}
Significance	****	****	NS	****	***	NS		****

8 months CA								
1 Day at RT								
Ontario								
Control	14.2 ^{B}	34 ^{D}	13.0 ^{AB}	515 ^{A}	8.9 ^{BC}	0 ^{C}	0 ^{C}	2.2 ^{BC}
SmartFresh	16.0 ^{A}	2 ^{D}	12.6 ^{BC}	509 ^{AB}	11.1 ^{BC}	0 ^{C}	0 ^{C}	2.2 ^{BC}
Quebec								
Control	11.4 ^{C}	38 ^{D}	11.9 ^{D}	316 ^{D}	2.2 ^{C}	22.2 ^{B}	0 ^{C}	0 ^{C}
SmartFresh	14.1 ^{B}	3 ^{D}	12.3 ^{CD}	365 ^{C}	0 ^{C}	44.4 ^{A}	4.4 ^{C}	0 ^{C}
7 Days at RT								
Ontario								
Control	11.4 ^{C}	254 ^{A}	12.7 ^{BC}	470 ^{B}	14.7 ^{B}	1.3 ^{C}	1.3 ^{C}	8.0 ^{BC}
SmartFresh	15.8 ^{A}	85 ^{C}	13.3 ^{A}	490 ^{AB}	5.7 ^{BC}	3.4 ^{C}	0 ^{C}	5.7 ^{BC}
Quebec								
Control	11.4 ^{C}	247 ^{A}	11.1 ^{E}	275 ^{E}	1.2 ^{C}	23.8 ^{B}	16.7 ^{B}	21.4 ^{A}
SmartFresh	11.8 ^{C}	169 ^{B}	11.8 ^{D}	308 ^{DE}	25.9 ^{A}	56.5 ^{A}	29.4 ^{A}	11.8 ^{B}
Significance	****	****	****	****	****	****	****	****
9 months CA								
1 Day at RT								
Ontario								
Control	13.4 ^{C}	34 ^{CD}	12.3 ^{A}	507 ^{A}	4.4 ^{CD}	0 ^{C}	8.9 ^{B}	0 ^{D}
SmartFresh	15.9 ^{A}	2 ^{D}	12.6 ^{A}	459 ^{B}	4.4 ^{CD}	4.4 ^{C}	2.2 ^{B}	0 ^{D}
Quebec								
Control	13.1 ^{C}	66 ^{C}	10.8 ^{B}	295 ^{E}	8.9 ^{CD}	6.7 ^{BC}	0 ^{B}	6.7 $^{B-D}$
SmartFresh	15.0 ^{B}	3 ^{D}	10.9 ^{B}	376 ^{D}	28.9 ^{B}	11.1 ^{BC}	8.9 ^{B}	4.4 ^{CD}

7 Days at RT								
Ontario								
Control	11.5 ^{E}	340 ^{A}	11.6 ^{AB}	450 ^{B}	7.4 ^{CD}	2.9 ^{C}	5.9 ^{B}	6.0 $^{B-D}$
SmartFresh	15.2 ^{B}	145 ^{B}	12.0 ^{A}	411 ^{C}	18.1 ^{BC}	13.3 ^{BC}	0 ^{B}	16.9 ^{BC}
Quebec								
Control	12.4 ^{D}	337 ^{A}	9.4 ^{C}	230 ^{F}	3.3 ^{D}	18.7 ^{B}	28.6 ^{A}	18.7 ^{B}
SmartFresh	13.4 ^{C}	294 ^{A}	9.2 ^{C}	290 ^{E}	60.7 ^{A}	34.5 ^{A}	33.3 ^{A}	45.2 ^{A}
Significance	****	****	****	****	****	****	****	****
10 months CA								
1 Day at RT								
Ontario								
Control	13.3 ^{C}	62 ^{CD}	12.7 ^{A}	429 ^{AB}	6.7 ^{AB}	6.7 ^{C}	11.1 ^{CD}	0 ^{D}
SmartFresh	15.7 ^{A}	3 ^{D}	12.8 ^{A}	446 ^{A}	8.9 ^{AB}	15.6 ^{BC}	0 ^{D}	0 ^{D}
Quebec								
Control	11.1 ^{DE}	83 ^{BC}	11.3 ^{C}	285 ^{D}	0 ^{B}	33.3 ^{B}	22.2 ^{BC}	11.1 $^{B-D}$
SmartFresh	14.3 ^{B}	4 ^{D}	11.2 ^{C}	279 ^{D}	6.7 ^{AB}	68.9 ^{A}	26.7 ^{BC}	6.7 ^{CD}
7 Days at RT								
Ontario								
Control	10.4 ^{E}	290 ^{A}	12.2 ^{B}	339 ^{C}	9.0 ^{AB}	17.9 ^{BC}	29.9 ^{B}	14.9 ^{B}
SmartFresh	14.4 ^{B}	147 ^{B}	12.7 ^{A}	397 ^{B}	14.8 ^{A}	28.4 ^{B}	18.5 ^{BC}	0 ^{D}
Quebec								
Control	9.3 ^{F}	227 ^{A}	11.2 ^{C}	230 ^{E}	0 ^{B}	30.9 ^{B}	48.5 ^{A}	36.8 ^{A}
SmartFresh	11.8 ^{D}	245 ^{A}	11.4 ^{C}	232 ^{E}	1.1 ^{B}	58.2 ^{A}	46.2 ^{A}	19.8 ^{B}
Significance	****	****	****	****	**	****	****	****

[1] Means within the same column for a given time with the same letter are not significantly different at $P < 0.05$. NS, *, **, ***, **** = not significant, and significant at $P < 0.05$, $P < 0.01$, $P < 0.001$, or $P < 0.0001$, respectively. Each value represents the average of 15 apples for ethylene, 45 and 65 for disorders on Day 1 and 7, respectively, and 30 for other indices.

New Apple Cultivars

Objective 2: To evaluate the effects of postharvest handling, 1-MCP technology, and storage regimes on the physical and sensory quality of new apple cultivars.

The Canadian Horticultural Council Apple Working Group chose the following apples for study: 'Honeycrisp', 'Creston', and 'Nicola'. The majority of work was performed on 'Honeycrisp', as this is the apple of greatest importance.

'Honeycrisp'

'Honeycrisp' apples were harvested on Sept. 10, 2012 from a commercial orchard near Simcoe, Ontario. Apples were transported to the *Apple Research Storage Lab* in Simcoe, within one hour of harvest. Fruit maturity upon arrival at the lab is presented in Table 4.

Table 4: Maturity of 'Honeycrisp' apples at harvest.

Blush (%)	Internal ethylene (ppm)	Firmness (lb-force)	Soluble solids (%)	Malic acid (mg/100 ml)	Starch index (1-8)
46	3.8	13.6	13.4	637	7.5

Experiment 1

The effect of SmartFresh treatment at 1 or 5 days after harvest was investigated.

Following harvest, nine boxes of 'Honeycrisp' apples were held for 5 days in a hallway with temperature fluctuating around 18^{o}C during the day to 10^{o}C overnight. Three boxes were treated with SmartFresh (1 ppm, 24 hr) at this temperature 1 day after harvest. After 5 days, all boxes were moved to air storage at 3^{o}C. Three boxes were then treated with SmartFresh (5 days after harvest) at 3^{o}C. Three boxes were left untreated.

There was little difference in 'Honeycrisp' treated with SmartFresh at 1 or 5 days after harvest (Tables 5 and 6). Lenticel breakdown was less in apples treated with SmartFresh at 1 day after harvest, compared to those treated at 5 days or not treated, after 4 months in air storage at 3^{o}C. This trend was also apparent after 6 months of storage, although not statistically significant.

Regardless of treatment time, 'Honeycrisp' treated with SmartFresh had lower internal ethylene concentration and higher malic acid than fruit not treated (Tables 5 and 6). Greasiness was also reduced with SmartFresh treatment 1 day after harvest, compared to non-treated fruit.

Table 5: Quality and disorders of 'Honeycrisp' apples without or treated with SmartFresh on 1 or 5 days after harvest and stored for 4 months at 3°C, plus 1 or 7 days at room temperature (RT, 22-23°C).

	Firmness (lb-force)	Internal ethylene (ppm)	Soluble solids (%)	Malic acid[1] (mg)	Greasiness (1-3)	Bitter pit[2] (%)	Lenticel bkdn (%)	Storage rots (%)
1 Day at RT								
No SmFr	15.8 ^{B}	49 ^{B}	14.8 ^{A}	551 ^{CD}	1.9 ^{B}	9 ^{B}	10 ^{A}	10 ^{B}
+ SmFr 1d	15.5 ^{B}	20 ^{C}	14.9 ^{A}	675 ^{A}	1.5 ^{C}	17 ^{A}	2 ^{B}	27 ^{A}
+ SmFr 5d	16.6 ^{A}	29 ^{C}	14.9 ^{A}	643 ^{AB}	1.9 ^{BC}	13 ^{AB}	8 ^{A}	24 ^{A}
7 Days at RT								
No SmFr	15.3 ^{B}	103 ^{A}	14.7 ^{A}	524 ^{D}	2.5 ^{A}	-	-	-
+ SmFr 1d	15.6 ^{B}	36 ^{BC}	14.8 ^{A}	606 ^{BC}	1.5 ^{C}	-	-	-
+ SmFr 5d	15.5 ^{B}	48 ^{B}	14.9 ^{A}	595 ^{BC}	1.8 ^{BC}	-	-	-
Significance[3]	***	****	NS	**	****	*	**	****

[1] Malic acid (mg) per 100 ml of juice.
[2] Severe bitter pit, which is often exacerbated by SmartFresh (Plate 7).
[3] Means within the same column with the same letter are not significantly different at $P < 0.05$.
NS, *, **, ***, **** = not significant, and significant at $P < 0.05$, $P < 0.01$, $P < 0.001$, or $P < 0.0001$, respectively.
Sample size was three reps of five apples for internal ethylene, ~55 for disorders, and 10 for other indices.
External disorders and rots were evaluated on Day 1. Three non-SmartFresh apples had soft scald.

Plate 7: Severe bitter pit in 'Honeycrisp' treated with SmartFresh.

Table 6: Quality and disorders of 'Honeycrisp' apples without or treated with SmartFresh on 1 or 5 days after harvest and stored for 6 months at 3°C, plus 1 or 7 days at room temperature (RT, 20-21°C).

	Firmness (lb-force)	Internal ethylene (ppm)	Soluble solids (%)	Malic acid[1] (mg)	Greasiness (1-3)	Soft scald (%)	Bitter pit[2] (%)	Lenticel bkdn (%)	Storage rots (%)
1 Day at RT									
No SmFr	15.7 ^{B}	60 ^{CD}	14.8 $^{A-C}$	609 ^{AB}	2.8 ^{A}	12 ^{A}	33 ^{B}	5 ^{A}	68 ^{A}
+ SmFr 1d	16.6 ^{A}	41 ^{DE}	15.0 ^{A}	662 ^{A}	2.5 ^{B}	7 ^{A}	53 ^{A}	0 ^{A}	80 ^{A}
+ SmFr 5d	15.8 ^{B}	36 ^{E}	15.0 ^{AB}	644 ^{AB}	2.7 ^{AB}	7 ^{A}	37 ^{AB}	5 ^{A}	67 ^{A}
7 Days at RT									
No SmFr	14.2 ^{D}	105 ^{A}	14.5 ^{BC}	583 ^{AB}	2.6 ^{AB}	-	-	-	-
+ SmFr 1d	15.0 ^{C}	81 ^{B}	14.5 ^{BC}	629 ^{AB}	2.5 ^{B}	-	-	-	-
+ SmFr 5d	14.7 ^{CD}	63 ^{BC}	14.4 ^{C}	560 ^{B}	2.7 ^{AB}	-	-	-	-
Significance[3]	****	****	*	*	*	NS	*	NS	NS

[1] Malic acid (mg) per 100 ml of juice.
[2] Severe bitter pit, which is often exacerbated by SmartFresh (Plate 7).
[3] Means within the same column with the same letter are not significantly different at $P < 0.05$.
NS, *, **** = not significant, and significant at $P < 0.05$or $P < 0.0001$, respectively.
Sample size was three reps of five apples for internal ethylene, ~55 for disorders, and 10 for other indices.
External disorders and rots were evaluated on Day 1.

Complementary sensory evaluations were performed at the *Vineland Research and Innovation Centre*. The associated sensory report can be found as a separate attached document, noted as Appendix 1. Following removal from cold storage, the apples used for tasting were held at room temperature for 5 days prior to the sensory evaluations.

After 4 months of storage, sensory triangle tests revealed perceived significant differences between all comparisons of non-treated and SmartFresh applied at 1 or 5 days after harvest. 'Honeycrisp' not treated with SmartFresh were rated higher for *mealy* texture and lower for *acid* taste. Apples treated with SmartFresh at 1 day after harvest had lower ratings for *oxidized red apple* flavor. After 6 months of storage, there were no statistically significant differences between attributes.

Experiment 2

The effects of CA storage and SmartFresh treatment were investigated.

Following harvest, 12 boxes of 'Honeycrisp' apples were held for 5 days in a hallway with temperature fluctuating around 18^{o}C during the day to 10^{o}C overnight. Six boxes were treated with SmartFresh (1 ppm, 24 hr) at this temperature 1 day after harvest. After 5 days, three boxes treated with SmartFresh and three boxes not treated were moved to air storage and into CA (3.0% O_2 + 1.5% CO_2) at 3^{o}C.

'Honeycrisp' stored in CA had lower internal ethylene concentrations, less greasiness, and fewer cracked fruit than those held in air storage (Table 7). SmartFresh-treated apples in CA also had the highest malic acid content. Some internal CO_2 injury (Plate 8) was found in CA-stored 'Honeycrisp' and SmartFresh had no effect on its incidence (Table 7). There was low incidence of soft scald (Plate 9), with no consistent effects of SmartFresh or CA. High incidence of storage rots were found in all treatments, which probably relates to the poor crop in 2012 due to early spring frosts.

Complementary sensory evaluations were performed at the *Vineland Research and Innovation Centre*. The associated sensory report can be found as a separate attached document, noted as Appendix 2. Following removal from cold storage, the apples used for tasting were held at room temperature for 5 days prior to the sensory evaluations.

'Honeycrisp' apples that were treated with SmartFresh and held in CA storage were perceived as being significantly different than fruit from the other treatment regimes. SmartFresh-treated apples stored in CA had lower perceived *sweet* taste and greater perceived *acid* taste. For apples not treated with SmartFresh, panelists did not discriminate between CA and air-stored apples.

Table 7: Quality and disorders of 'Honeycrisp' apples treated with or without SmartFresh and stored in air or CA (3.0% O_2 + 1.5% CO_2) at 3°C for 6 months, plus 1 or 7 days at room temperature (RT, 21-22°C).

	Firmness (lb-force)	Internal ethylene (ppm)	Soluble solids (%)	Malic acid[1] (mg)	Greasiness (1-3)	Internal CO_2 injury (%)	Soft scald (%)	Bitter pit[2] (%)	Cracked (%)	Storage rots (%)
1 Day at RT										
Air										
No SmFr	15.0 AB	75 B	14.2 AB	523 AB	2.9 A	0 B	1 B	4 B	4 A	13 B
+ SmFr	15.4 A	35 C	14.9 A	552 AB	2.6 B	0 B	4 AB	7 AB	4 A	30 A
CA										
No SmFr	15.4 A	12 D	14.9 A	546 AB	1.7 C	9 A	5 A	11 A	1 B	31 A
+ SmFr	15.5 A	0.7 D	14.9 A	593 A	1.0 E	0 B	3 AB	5 B	0 B	24 A
7 Days at RT										
Air										
No SmFr	14.2 C	126 A	13.7 B	329 C	2.9 A	0 B	-	-	-	-
+ SmFr	14.5 BC	72 B	14.5 AB	501 BC	2.4 B	0 B	-	-	-	-
CA										
No SmFr	14.4 BC	78 B	14.4 AB	411 AB	1.7 C	5 AB	-	-	-	-
+ SmFr	14.3 BC	5 D	14.4 AB	588 A	1.3 D	7 A	-	-	-	-
Significance[3]	****	****	*	*	****	****	*	*	**	****

[1] Malic acid (mg) per 100 ml of juice.

[2] Severe bitter pit, which is often exacerbated by SmartFresh (Plate 7).

[3] Means within the same column with the same letter are not significantly different at $P < 0.05$. NS, *, **, **** = not significant, and significant at $P < 0.05$, $P < 0.01$, or $P < 0.0001$, respectively. Sample size was three reps of five apples for internal ethylene, ~55 for disorders, and 10 for other indices. External disorders and rots were evaluated on Day 1, while the incidence of internal CO_2 injury was counted using three reps of 15 and 40 fruit on Day 1 and 7, respectively.

Plate 8: Internal CO_2 injury in CA-stored ‘Honeycrisp’.

Plate 9: Soft scald in ‘Honeycrisp’.

Experiment 3

The effect of delayed CA storage was investigated.

Following harvest, 24 boxes of 'Honeycrisp' apples were held for 5 days in a hallway with temperature fluctuating around 18°C during the day to 10°C overnight. Twelve boxes were treated with SmartFresh (1 ppm, 24 hr) at this temperature 1 day after harvest. After the 5 days, three boxes treated with SmartFresh and three boxes not treated were moved into CA (3.0% O_2 + 1.5% CO_2) storage at 3°C (no delay), while all remaining boxes stayed in air storage at 3°C. After 2 weeks, 1 month and 3.5 months, three boxes treated with SmartFresh and three boxes not treated were also moved into CA storage.

As a main effect, delayed CA reduced the incidence of soggy breakdown (0-1 vs. 3%) but increased lenticel breakdown (6-11 vs. 2%) and severe bitter pit (7-16 vs. 5%). In addition, delayed CA reduced internal CO_2 injury (0-1 vs. 2%) and more so with longer delay. These effects of delayed CA were more pronounced in apples not treated with SmartFresh, compared to those with SmartFresh (Table 8).

Delayed CA had no consistent effects on other fruit quality measurements (Table 8). There was high incidence of storage rots in all treatment regimes, but SmartFresh reduced the percentage overall. Again, the overall high incidence of storage rots was likely due to the poor crop in 2012 due to early spring frosts.

Complementary sensory evaluations were performed at the *Vineland Research and Innovation Centre*. The associated sensory report can be found as a separate attached document, noted as Appendix 3. Following removal from cold storage, the apples used for tasting were held at room temperature for 5 days prior to the sensory evaluations.

Delayed CA had more of an effect on the sensory properties of 'Honeycrisp' treated with SmartFresh than those without SmartFresh. Apples differed in perceived intensities for *sweet* and *acid* taste, *floral* aroma/flavor, and *juicy* texture. However, the significant differences among delayed CA treatments were not consistent. Therefore, no solid conclusions related to sensory attributes could be made based on this study alone.

Table 8: Quality and disorders of 'Honeycrisp' apples treated with or without SmartFresh and stored in air for 0, 2 weeks, 1 month, or 3.5 months and then in CA (3.0% O_2 + 1.5% CO_2) at 3°C until 6 months, plus 1 or 7 days at room temperature (RT, 19-20°C).

	Firmness (lb-force)	Internal ethylene (ppm)	Soluble solids (%)	Malic acid[1] (mg)	Internal CO_2 injury (%)	Soggy bkdn (%)	Soft scald (%)	Bitter pit[2] (%)	Lenticel bkdn (%)	Storage rots (%)
1 Day at RT										
No SmFr										
No delay	15.0 F	11 EF	14.8 A-C	632 A-D	4 A	7 A	1 AB	6 CD	1 D	88 A
2 wk delay	15.5 C-F	5 EF	14.9 AB	674 AB	2 AB	4 AB	4 AB	15 AB	9 AB	49 C
1 mo delay	15.9 A-E	7 EF	14.2 CD	546 EF	0 B	0 C	6 A	11 A-C	10 AB	67 B
3.5 mo delay	16.2 A-D	15 E	14.1 D	571 D-F	0 B	0 C	3 AB	15 AB	15 A	34 D
+ SmFr										
No delay	15.8 B-E	1 F	14.4 B-D	569 D-F	0 B	2 BC	2 AB	4 D	2 CD	28 D
2 wk delay	16.6 A	1 F	15.0 AB	669 A-C	0 B	0 C	4 AB	8 B-D	6 B-D	44 C
1 mo delay	16.3 A-C	1 F	14.9 AB	631 A-D	0 B	0 C	1 B	3 D	3 CD	10 E
3.5 mo delay	15.6 C-F	3 F	14.9 A-C	569 D-F	0 B	0 C	3 AB	17 A	7 BC	44 C
7 Days at RT										
No SmFr										
No delay	14.3 G	68 A	15.0 AB	602 C-E	3 AB	3 A-C	-	-	-	-
2 wk delay	16.5 AB	51 BC	15.1 AB	693 A	2 AB	2 BC	-	-	-	-
1 mo delay	15.4 D-F	44 C	14.8 A-C	520 F	0 B	0 C	-	-	-	-
3.5 mo delay	15.9 A-E	56 B	14.9 A-C	607 B-E	0 B	0 C	-	-	-	-
+ SmFr										
No delay	15.6 C-E	3 F	14.7 A-D	584 D-F	2 AB	2 BC	-	-	-	-
2 wk delay	15.9 A-E	3 F	15.4 A	667 A-C	0 B	0 C	-	-	-	-
1 mo delay	16.1 A-D	3 F	15.0 AB	593 DE	2 AB	0 C	-	-	-	-
3.5 mo delay	15.3 EF	27 D	15.0 AB	564 D-F	1 AB	0 C	-	-	-	-
Significance[3]	****	****	*	****	*	***	*	****	****	****

[1] Malic acid (mg) per 100 ml of juice.

[2] Severe bitter pit, which is often exacerbated by SmartFresh (Plate 7).

[3] Means within the same column with the same letter are not significantly different at $P < 0.05$.
*, ***, **** = significant at $P < 0.05$, $P < 0.001$ or $P < 0.0001$, respectively.
Sample size was three reps of five apples for internal ethylene, ~85 for disorders, and 10 for other indices.
External disorders and rots were evaluated on Day 1, while internal disorders were counted using three reps of 15 and 70 fruit on Day 1 and 7, respectively.

'Creston'

'Creston' = 'Golden Delicious' × NJ 381049

Fruit ripening of 'Creston' was followed at one orchard near Simcoe, Ontario. This orchard (Orchard 1) was also used in the previous two years of study. Fruit maturity information is presented in Table 9. As observed in previous years, internal ethylene concentration remained relatively low as substantial starch degradation occurred.

The DA meter is a new technology for evaluating fruit maturity, which is based on non-destructive chlorophyll measurements. It is interesting to note that the DA meter values of 'Creston' in this study decreased consistently throughout the maturation period represented in Table 9. Therefore, there is potential for the DA meter to be a useful measure of fruit maturity in 'Creston'. This is not the case for several other apple cultivars that were studied within other projects.

Table 9: Maturity of 'Creston' apples during 2012 season.

	Diameter (cm)	Blush (%)	IEC[1] (ppm)	Firmness (lb-force)	SSC[2] (%)	Malic acid (mg/100 ml)	Starch index (1-8)[3]	DA meter value
Orchard 1								
Sept. 10	6.3	22.0	0.1	16.7	14.6	771	3.9	0.86
Sept. 14	7.7	38.5	8.3	16.8	13.7	670	4.8	0.72
Sept. 21	7.7	47.5	0.5	15.3	14.5	671	4.8	0.65
Sept. 24	7.7	41.5	1.4	15.2	15.1	671	7.2	0.51

[1] IEC = internal ethylene concentration
[2] SSC = soluble solids concentration
[3] Generic Starch-Iodine Index Chart for Apples (Cornell University)

'Creston' apples for the storage studies were harvested from Orchard 1 on Sept. 24th, 2012. Fruit maturity at harvest time is within Table 9. Apples were transported to the *Apple Research Storage Lab* in Simcoe within 2 hours of harvest and cooled overnight to 3°C. Half of the apples were then treated with SmartFresh (1 ppm, 1-MCP) for 24 hours. Treated and non-treated fruit were subsequently stored for 2 or 4 months in air at 0°C.

After 2 months of air storage at 0^{o}C plus 7 days at room temperature, ‘Creston’ apples treated with SmartFresh were firmer (+1.5 lb) than those not treated. SmartFresh also substantially reduced internal ethylene concentration (Table 10).

After 4 months of air storage, SmartFresh-treated fruit continued to be firmer (+2.8 lb) and have less internal ethylene (Table 10, Plate 10). Treated apples also had significantly lower incidence of lenticel breakdown, compared to those with no SmartFresh. There was high incidence of storage rots after 4 months, but this was significantly reduced by SmartFresh.

Plate 10: ‘Creston’ after 4 months in air storage at 0^{o}C.

Table 10: Quality of 'Creston' apples treated with or without SmartFresh and held in air storage for 2 or 4 months at 0-1°C, plus 1 or 7 days at room temperature (~18-20°C).

	Firmness (lb-force)	Internal ethylene (ppm)	Soluble solids (%)	Malic acid[1] (mg)	Bitter pit (%)	Severe bitter pit[2] (%)	Lenticel bkdn (%)	Storage rots (%)
2 Months								
1 Day at RT								
Control	15.8 A	62 B	15.0 A	649 A	20 A	0	0	0 A
SmartFresh	16.0 A	2 C	14.8 A	606 AB	11 A	0	0	2 A
7 Days at RT								
Control	14.1 B	183 A	15.8 A	567 B	16 A	0	0	0 A
SmartFresh	15.6 A	1 C	15.0 A	623 AB	5 A	0	0	2 A
Significance[3]	****	****	NS	*	NS	-	-	NS
4 Months								
1 Day at RT								
Control	13.8 B	83 B	15.6 A	499 AB	13 A	27 A	10 AB	43 A
SmartFresh	15.3 A	2 C	15.6 A	558 A	3 A	13 A	7 B	3 C
7 Days at RT								
Control	12.9 C	234 A	15.2 A	426 B	13 A	23 A	21 A	28 AB
SmartFresh	15.7 A	1 C	15.0 A	560 A	10 A	22 A	6 B	14 BC
Significance[3]	****	****	NS	*	NS	NS	*	***

[1] Malic acid (mg) per 100 ml of juice.
[2] Severe bitter pit, which is often exacerbated by SmartFresh.
[3] Means within the same column with the same letter are not significantly different at $P < 0.05$.
NS, *, ***, **** = not significant, and significant at $P < 0.05$, $P < 0.001$ or $P < 0.0001$, respectively.
Sample size was three reps of five apples for internal ethylene, 15 for disorders, and 10 for other indices.

'Nicola'

'Nicola' (SPA440) = 'Splendour' × 'Gala'

Fruit ripening of 'Nicola' was noted within an orchard in the Niagara region of Ontario (Fonthill). Fruit maturity information is presented in Table 11. There was considerable advancement in fruit softening and starch degradation from September 17th to 20th. In contrast to 'Creston', the DA meter values for 'Nicola' did not appear to decrease in direct association with other maturity indices.

Table 11: Maturity of 'Nicola' apples during 2012 season.

	Diameter (cm)	Blush (%)	IEC[1] (ppm)	Firmness (lb-force)	SSC[2] (%)	Malic acid (mg/100 ml)	Starch index (1-8)[3]	DA meter value
Sept. 11	7.3	66	0.4	19.4	14.3	671	3.6	0.69
Sept. 17	7.0	72	1.2	19.7	16.1	805	3.8	0.50
Sept. 20	7.6	74	2.5	17.3	15.6	671	6.2	0.49

[1] IEC = internal ethylene concentration
[2] SSC = soluble solids concentration
[3] Generic Starch-Iodine Index Chart for Apples (Cornell University)

'Nicola' apples for the storage studies were harvested on Sept. 20th, 2012. Fruit maturity at harvest time is within Table 11. Apples were transported to the *Apple Research Storage Lab* in Simcoe within 2 hours of harvest and cooled overnight to 3°C. Half of the apples were then treated with SmartFresh (1 ppm, 1-MCP) for 24 hours. Treated and non-treated fruit were subsequently stored at 0°C for 3 months in air storage or for 6 months in CA (2.5% O_2 + 2.5% CO_2).

Air-stored 'Nicola' treated with SmartFresh were firmer (+2 lb) than those not treated after 2 months plus 7 days at room temperature (Table 12). Treated apples also had lower internal ethylene concentration and greater acidity at this time, compared to fruit not treated.

After 6 months of CA storage, there was little effect of SmartFresh on fruit quality, as the apples maintained firmness and acidity (Plate 11). Lenticel breakdown incidence was high after 7 days at room temperature and SmartFresh tended to aggravate this disorder.

Table 12: Quality and disorders of 'Nicola' apples treated with or without SmartFresh and stored for 3 months in air storage or 6 months in CA (2.5% O_2 + 2.5% CO_2) at 0-1°C, plus 1 or 7 days at room temperature (RT, ~19-21°C).

	Firmness (lb-force)	Internal ethylene (ppm)	Soluble solids (%)	Malic acid (mg)[1]	Lenticel breakdown (%)	Storage rots (%)
3 Months - Air						
1 Day at RT						
Control	19.3 ^{BC}	2.0 ^{B}	16.8 ^{B}	552 ^{BC}	6.7 ^{AB}	0 ^{A}
SmartFresh	19.6 ^{B}	0.2 ^{B}	17.5 ^{AB}	569 ^{B}	11.1 ^{A}	0 ^{A}
7 Days at RT						
Control	18.9 ^{C}	9.3 ^{A}	18.0 ^{A}	522 ^{C}	2.2 ^{B}	0 ^{A}
SmartFresh	20.9 ^{A}	1.1 ^{B}	18.6 ^{A}	622 ^{A}	7.5 ^{AB}	0.8 ^{A}
Significance[2]	****	**	*	**	*	NS
6 Months - CA						
1 Day at RT						
Control	19.2 ^{A}	0.1 ^{C}	16.7 ^{A}	609 ^{A}	8.9 ^{C}	0 ^{A}
SmartFresh	19.7 ^{A}	0.1 ^{C}	16.7 ^{A}	588 ^{A}	0 ^{C}	0 ^{A}
7 Days at RT						
Control	19.6 ^{A}	1.0 ^{A}	17.3 ^{A}	621 ^{A}	23.2 ^{B}	4.1 ^{A}
SmartFresh	19.5 ^{A}	0.6 ^{B}	17.3 ^{A}	603 ^{A}	39.2 ^{A}	6.5 ^{A}
Significance[2]	NS	****	NS	NS	****	NS

[1] Malic acid (mg) per 100 ml of juice.

[2] Means within the same column with the same letter are not significantly different at $P < 0.05$. NS, *, **, **** = not significant, and significant at $P < 0.05$, $P < 0.01$ or $P < 0.0001$, respectively. Sample size was three reps of five apples for internal ethylene, 15 for disorders, and 10 for other indices. Day 7 disorder evaluations included another 60 apples per rep.

Plate 11: ‘Nicola’ apples after 6 months in CA (2.5% O_2 + 2.5% CO_2) storage at 0^oC.

DPA Application

Objective 3: To investigate the application of diphenylamine using aerosol or thermo-fogging technology in commercial apple storage rooms.

Diphenylamine (DPA) is a registered growth regulator for postharvest use on apples to reduce superficial scald development. DPA has also been shown to control external CO_2 injury in apples, such as 'Empire' and 'McIntosh'.

There have been two DPA formulations registered in Canada: 1) No-Scald DPA EC 283 (31% a.i.) from Decco and 2) Shield DPA 15% Super Refund (15% a.i.) from Pace International. These two products are emulsifiable concentrates and thus are most commonly applied as a postharvest drench treatment. However, the aqueous application of DPA generates huge amounts of waste, which has become difficult to dispose of. In addition, the reuse and recirculation of the emulsion leads to accumulation of pathogens in the drencher, which can increase pathogen presence and decay incidence in the stored apples.

Application of DPA as a fog or aerosol can avoid the above problems. Overall, this type of treatment is more environmentally friendly, requires no water and releases no condensates during the application. There is also no need for subsequent product disposal, and the process eliminates fruit decay caused by the accumulation of pathogens in a drencher.

As a result of this project, two advanced DPA products were registered for use on apples in Canada…

1) **Decco DPA Aerosol** received Canadian registration in August 2011.
   It was subsequently used commercially during the 2011 and 2012 harvest seasons.

2) **Pace EcoFog 100 (DPA)** received Canadian registration in June 2012.
   However, commercial use was delayed by Pace until the 2012 harvest season.

Pace fungicide EcoFog 160 (Pyrimethanil) also received Canadian registration for use on apples in July 2013. However, there has not been much commercial use of this product to date.