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Project leader:	Richard Colgan
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Key staff:	Richard Colgan (NRI) Karen Thurston (EMR) Angela Berrie (EMR) Debbie Rees (NRI)
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Industry Representative:	Nigel Bardsley
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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Dr Richard Colgan
Research Fellow
Natural Resources Institute, University of Greenwich

Signature ..... Date .....

Report authorised by:

Dr John Orchard
Director of Research
Natural Resources Institute, University of Greenwich

Signature ..... Date .....

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GROWER SUMMARY

Headline

From the first year's work, storing Conference beyond the existing six month window appears to be best achieved by using the standard recommended temperatures.

Background and expected deliverables

With the granting of an EAMU for SmartFresh™ (1-MCP) on pears, opportunities exist to explore the modification of existing storage recommendations for Conference pears. Early experience with SmartFresh™ on Conference has found that pears often fail to ripen properly after removal from store and in some cases have lost their ability to respond to ripening cues. Nevertheless subsequent experimental trials conducted on behalf of Agrofresh have indicated that by modifying storage temperature, or reducing application rates from the usual recommended concentration of 625 ppb to 325 ppb, Conference pears retain their ability to ripen. The introduction of a low concentration of external source of ethylene during SmartFresh treatment™ has also produced promising results.

The current recommendations for pear storage require rapid cooling to remove the field-heat and reduce fruit temperature to 4°C within 2-3 days of store loading followed by a further reduction to -1°C within 7-10 days of loading. In some cases rapid cooling to -1°C has been difficult to achieve particularly in older stores. Such low storage temperatures can lead to fruit stalk end shrivel in some stores. To avoid this, bins can be covered but this further increases storage costs.

The introduction of new protocols to counteract the problems associated with SmartFresh™ and delayed ripening, offer the opportunity of further research to improve pear quality and extension of storage-life.

It is worth researching the effect of reducing the dose of SmartFresh™ currently recommended (625 ppb), or to store at higher temperatures than currently recommended. Reducing the dose rate to 325 ppb has been found to be effective where pear maturity is clearly defined and pears are to be marketed after 6 and 9 months storage.

The most effective protocol must evaluate not only the propensity to ripen ex-store, but also the amount of shrivel, background colour and the incidence of rotting, both ex-store and during shelf-life.

The effect on pear storage life of ethylene removal during storage should also be tested.

The project aims to improve fruit quality and reduce costs of Conference pear storage by using SmartFresh™. Key to achieving this aim will be the identification of protocols whereby pears retain their ability to ripen following SmartFresh™ treatment.

Specific objectives are:

1. To identify an optimum method of SmartFresh™ treatment and storage for Conference pears.

    1.1 To identify the optimum storage temperature following an application of SmartFresh™.

    1.2. To assess the effects of exposure of fruit to low concentrations of external ethylene in conjunction with SmartFresh™ treatment with a view to maximising the benefits of objective 1.1.

    1.3. To compare the effect of SmartFresh™ application with ethylene scrubbing during storage.

2. To quantify the economic benefits of the identified optimum method of post-harvest treatment and storage.

3. To disseminate results obtained through publications, the EMRA members day on fruit storage and training days where appropriate.

Summary of the project and main conclusions

Conference pears were harvested from two orchards in Kent on the 1st September 2011 and transported to the Produce Quality Centre at East Malling Research. Fruits were randomized with misshapen, damaged, small and diseased fruits discarded. Fruits were cooled for 48 hours to reach storage temperatures before SmartFresh™ was applied at the temperatures and application rates outlined in the table below, with or without the addition of ethylene. In addition, the use of E^+ formulated palladium catalyst was also tested:

Treatment	Code	Temperature regime		
		-0.5 to -1°C	0.5 to 1.0°C	1.5 to 2.0°C
Control, no treatment	C	√	√	√
24 h treatment with SmartFresh™ (625 ppb)	A	√	√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 300 ppb ethylene.	B1		√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 600 ppb ethylene	B2		√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 900 ppb ethylene	B3		√	√
24 h treatment with SmartFresh™ (325 ppb)	D	√	√	√
Ethylene scrubbing by E+ (palladium based) throughout storage period	E		√	√

The results from the 2011-2012 season indicate that extending the storage period for Conference pear beyond the existing 6-month window is most likely to be achieved through storing at lower temperatures of 1°C or less. Two contrasting orchards were included in these trials. The effectiveness of SmartFresh™ varied according to orchard; SmartFreshTM-treated fruit from orchard 40 softened at a slower rate.

Storage at 1.5-2.0°C led to a loss of firmness during prolonged storage in both orchards and SmartFresh failed to maintain firmness above the commercially acceptable threshold (60N) after 3 months storage. More importantly, a rapid loss of background green colour was observed in fruit from all treatments stored at 1.5-2.0°C along with a greater incidence of post-harvest rotting in fruit stored beyond 3 months. In addition, internal carbon dioxide injury was present in fruit inspected after 9 months of storage.

The ex-store firmness of pears stored at 0.5-1.0°C and -0.5 to -1.0°C during the first 6 months of CA storage were similar and no treatment differences between SmartFresh and control fruit were observed. Maintaining the firmness of pears in long-term storage required storage at the standard -0.5 to -1.0°C regime. However, there was no significant effect of SmartFresh on ex-store firmness of conference pears during extended periods of storage.

The rate of softening of pears during shelf-life was influenced by SmartFresh™ and the duration of storage. Pears entering shelf-life after 3 months storage exhibited a 1-2 day delay before changes in firmness were observed. Pears treated with SmartFresh™ (625 ppb) softened at a slower rate between 2 and 6 days, with the delay in softening more pronounced in fruits stored at lower temperatures. However, fruits from each treatment reached an eating quality firmness of 1.5 kg by between 5-7 days. Pears entering shelf-life after 6 or 9 months storage showed no delay in softening and at this stage in the storage life SmartFresh was only marginally effective at delaying softening during shelf-life of pears from orchard 40.

Financial benefits

- No financial benefits have been identified from this project to date.

Action points for growers

- No action points have yet been identified.

SCIENCE SECTION

Introduction

With the granting of an EAMU for SmartFresh™ (1-MCP) on pears, opportunities exist to explore the modification of existing storage recommendations for Conference pears. Early experience with SmartFresh™ on Conference has found that pears often fail to ripen properly after removal from store and in some cases have lost their ability to respond to ripening cues. Nevertheless subsequent experimental trials conducted on behalf of Agrofresh have indicated that by modifying storage temperature, or reducing application rates from the usual recommended level of 625 ppb to 325 ppb, Conference pears retain their ability to ripen (Mark Tully *personal communication*). The introduction of a low concentration of external source of ethylene during SmartFresh™ treatment has also produced promising results. The current recommendations for pear storage require rapid cooling to remove the field-heat and reduce fruit temperature to 4°C within 2-3 days of store loading, followed by a further reduction to -1°C within 7-10 days of loading. In some cases rapid cooling to -1°C has been difficult to achieve particularly in older stores. Such low storage temperatures can lead to fruit stalk end shrivel in some stores. To avoid this, bins can be covered but this further increases storage costs.

The introduction of new protocols to counteract the problems associated with SmartFresh™ and delayed ripening, offer the opportunity of further research to improve pear quality and extension of storage-life.

It is worth researching the effect of reducing the dose of SmartFresh™ currently recommended (625 ppb), or to store at higher temperatures than currently recommended. Reducing the dose rate to 325 ppb has been found to be effective where pear maturity is clearly defined and pears are to be marketed after 6 and 9 months storage.

SmartFresh™ inhibits ethylene from binding to receptors and slows down the ripening process. The introduction of low concentrations of ethylene at the same time as a SmartFresh™ treatment may allow activation of a limited number of receptors whilst SmartFresh™ binds to remaining receptors, slowing down that natural rate of ripening of pears during storage whilst allowing fruit to ripen fully during shelf-life. It is anticipated that this procedure will facilitate the use of higher temperatures and therefore save energy costs.

The most effective protocol must evaluate not only the propensity to ripen ex-store, but also the amount of shrivel, background colour and the incidence of rotting, both ex-store and during shelf-life.

The effect on pear storage life of ethylene removal during storage is also being tested using a new palladium-based absorbent that has previously been demonstrated to be capable of removing ethylene from the storage environment.

Project aim(s):

To improve fruit quality and reduce costs of Conference pear storage by using SmartFresh™. Key to achieving this aim will be the identification of protocols whereby pears retain their ability to ripen following SmartFresh™ treatment.

Project objective(s):

1. To identify an optimum method of SmartFresh™ treatment and storage for Conference pears.
    1.1 To identify the optimum storage temperature following an application of SmartFresh™.
    1.2. To assess the effects of exposure of fruit to low levels of external ethylene in conjunction with SmartFresh™-treatment with a view to maximising the benefits of objective 1.1.
    1.3. To compare the effect of SmartFresh™ application with ethylene scrubbing during storage.
2. To quantify the economic benefits of the identified optimum method of post-harvest treatment and storage.
3. To disseminate results obtained through publications, the EMRA members day on fruit storage and training days where appropriate.

Materials and methods

Conference pears from two orchards (referred to as '39' and '40') from the same farm were harvested on the 1st September 2011, and transported to the Produce Quality Centre, East Malling Research whereupon fruit were randomized. All damaged, diseased and misshapen fruit were discarded.

The storage treatments tested are summarized in Table 1. For each of treatments C, A, D and E, approximately 100 fruits were loaded into each of three replicate plastic crates for each of the two orchards and subject to forced air cooling for 36 hours prior to SmartFresh™ treatment for treatments A, D and E.

An additional aspect of the trial was to investigate the impact of SmartFresh™ and storage temperature on disease development and spread in pears inoculated with *Botrytis*. Ten conference pears previously inoculated with spores of Botrytis conidia were evenly distributed in one crate per orchard per treatment.

One CA chamber (360 litre) was used for each of these treatments. Thus for each treatment there were two uninoculated boxes and one inoculated box for each of two orchards, giving a total of six boxes.

Treatments B1,B2 and B3 were carried out using orchard 39 only, without Botrytis inoculation and the treatments stored within common chambers. Thus there were two boxes per treatment at each temperature.

SmartFresh™ was applied at a standard dose of 625 ppb, a half dose of 312 ppb, or full rate (625 ppb) treatment was combined with a small dose of 300, 600 or 900 ppb of ethylene (Orchard 39 fruit only). Untreated controls and an additional scrubbing treatment (E^+) were also included.

Table 1: Summary of storage treatments tested

Treatment	**Code**	**Temperature regime**		
		-0.5 to -1°C	0.5 to 1.0°C	1.5 to 2.0°C
Control, no treatment	C	√	√	√
24 h treatment with SmartFresh™ (625 ppb)	A	√	√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 300 ppb ethylene.	B1		√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 600 ppb ethylene	B2		√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 900 ppb ethylene	B3		√	√
24 h treatment with SmartFresh™ (325 ppb)	D	√	√	√
Ethylene scrubbing by E^+ (palladium based) throughout storage period	E		√	√

CA storage (1.2% O_2 <1% CO_2) was established at three storage temperatures: 1.5 to 2.0°C, 0.5 to 1.0°C and -0.5 to -1.0°C. O_2 concentrations were allowed to establish through respiration. Where final CA establishment was slow to achieve, some additional nitrogen flushing was used in cabinets once O_2 had depleted below 5%. CO_2 was maintained at <1.0% by the attachment of external $Ca(OH)_2$ (lime) scrubbers.

Harvest maturity assessments of fruit were made by starch clearance, using iodine staining and colour assessment using a Minolta colour meter in Lab mode. Firmness was measured using a motorised penetrometer (Lloyd LRX) with an 8 mm probe. % brix was measured on pear juice samples and fruits were cut longitudinally to inspect for internal physiological

disorders and internal rots. Percentage dry matter content and mineral analysis of fruit were also assessed at harvest.

CA conditions were maintained using an ICA 66 gas monitoring system with automatic injection of air and nitrogen to maintain CA. Assessments were undertaken after three, six and nine months of storage. A two x 10 fruit sample of assessment of fruit quality was made on pears from each orchard from each treatment, immediately on removal from CA storage. In addition a 25 fruit sample of pears from each orchard*treatment combination was subject to shelf-life assessment at 18°C where 5 fruits were removed after two, three, five, six and eight days of shelf-life to determine the length of time fruit took to reach an optimum eating quality firmness of 15N (1.5 kg).

Results

Colour- Ex-store

Storage of pears at 1.5-2.0°C led to a rapid loss of green colour (ex-store) which was not halted by the application of SmartFresh^{TM} . Storage at lower temperatures of 0.5-1.0 or the standard -0.5 to -1.0 retained background green colour for longer (Table 2).

Firmness-Ex-store

Data from the first year of this trial showed SmartFresh^{TM} treatment provided only a minor benefit in maintaining fruit firmness during extended storage. The lack of treatment efficacy was most probably due to the high background ethylene concentration caused by rotting fruit. Storage temperature and orchard consignments had the largest effects on ex-store firmness (Table 3) with pears from orchard 40 stored at the standard storage temperature of -0.5°C to -1.0°C maintaining the best firmness (57-65 N; 5.7-6.5 Kg). Fruit stored at the higher temperature of 1.5-2.0°C softened rapidly after 3 months storage. Storage at the intermediate storage temperature (0.5-1.0°C) slowed the rate of firmness decline, but firmness readings declined below commercially acceptable limits after 3 months of storage.

% Brix- Ex-store

There was no evidence that temperature or SmartFresh^{TM} altered the soluble solid content of fruit during storage (Table 5).

Rotting-Ex-store

The incidence of rotting (*Botrytis cinerea*) was most prevalent after 3 months storage. Pears from orchard 39 had a higher incidence of rotting than orchard 40 (Table 4). In general, storage at higher temperatures (1.5-2.0°C) resulted in a higher incidence of rotting.

Application of full rate SmartFresh™ increased the incidence of rotting during storage in pears from orchard 39 but the effect was not replicated in the other orchard consignment.

% Shrivel-Ex-store

Stalk-end shrivel was most noticeable at lower temperature storage (-0.5 to -1.0°C) and pears from orchard 39 appeared to suffer from the greatest amount of shrivel (Table 7). No effect of SmartFresh™ was observed on the incidence of shrivel.

% CO_2-Injury – Ex-store

The incidence of internal CO_2-Injury was observed in fruit stored for 9 months at 1.5-2.0°C but was absent from consignments stored at lower temperatures (Table 6). Pears from orchard 39 exhibited the highest incidence of the disorder and this was aggravated by the application of SmartFresh™ in pears stored at high-temperatures.

Ethylene application trial

Due to the rapid decline in firmness across all treatments the application of a small dose of ethylene at the time of SmartFresh™ application had no effect on fruit firmness, but increased the incidence of rotting (10-22%) compared to the control (5-6%) and the incidence of rotting (*Botrytis cinerea*) increased with storage temperature. In addition, to elevating rots, the addition of ethylene at the higher storage temperature led to an increase in internal CO_2-injury and internal breakdown of the flesh.

% Weight loss

Weight loss from fruit ranged from 0.6%-2.0% across treatments in fruit stored at -0.5 to -1.0°C and +0.5 to 1°C; there were no clear treatment effects on weight loss from pears from either orchard. At higher temperatures (1.5-2.0°C), the combination of additional ethylene at harvest and SmartFresh™ led to an increase in water loss (~5%) but this may be a direct result of an increase in rotting observed in these treatments.

Shelf-life

After 3 months storage at 1.5-2.0°C a delay ‘lag phase’ in softening of 1-2 days was observed in fruits stored across all treatment and temperature combinations (Fig 1A, 1D). Interestingly, once pears started to soften the rate of firmness decline was rapid. In later inspections (6 & 9 months) softening of pears commenced immediately upon entering shelf-life conditions. However the rate of softening was more gradual, and the time to reach 1.5 kg (15 N) (considered to be optimum eating quality), was between 6-7 days in each case (Fig 2A, 2D, 3A and 3D).

In general, pears from orchard 40 softened at a slower rate, during the early stages of shelf-life compared to fruit from orchard 39. However, the number of days taken to reach eating quality in both orchards was similar. Pears from orchard 39 and 40 treated with full rate SF, softened to 1.5 kg in 7 days, compared to 6 days for the untreated fruit and fruit treated with half rate SmartFresh™. At higher storage temperatures, storage beyond 3 months led to a decline in ex-store firmness and rapid softening in shelf-life.

After 3 months storage at the intermediate storage temperature of 0.5-1.0°C, pears treated with SmartFresh™ (625 ppm) softened to 1.5 kg in 7 days and SmartFresh™- (312 ppm) and control fruit within 6 days (Fig 1B, 1E). The effect of delayed softening by SmartFresh™ was not observed in shelf-life samples tested after 6 and 9 months of storage.

Storage of SmartFresh™ treated pears at the standard storage temperature (-0.5 to -1.0°C) maintained ex-store firmness for longer and this was also transcribed into delayed softening rates during shelf-life. After 3 months storage, the length of time taken to reach an eating quality firmness of 1.5 kg was 7 days for SmartFresh™ (625 ppb) treated pears from orchard 40 and 6 days for untreated control fruit. SmartFresh™ (312 ppb) treated fruit took between 6-6.5 days to reach eating quality firmness (Fig 1C, 1F). The initial rate of softening in pears treated with full rate SmartFresh™ was slower in pears but increased during the later stages of shelf-life.

Softening patterns of fruit coming out of (-0.5 to -1.0°C) storage at 6 months were similar to earlier inspections but after 9 months of storage softening curves of all treatments were similar.

Scrubbing of ethylene with E+

Scrubbing of ethylene with E+ did not alter the softening rates of pears. However, measurement of ethylene within the chambers indicates that the formulation used in this trial was not effective in removing the ethylene.

Table 1.1: Harvest maturity of Conference pears from 2 orchards (39 and 40)

Orchard	Green Minolta - a	Yellow Minolta b	Firmness	%SS	%DM
39	-17.14	40.54	63.95	12.60	16.20
SE	*0.44*	*0.355*	*1.75*	*0*	*0.47*
40	-17.51	40.88	64.25	12.70	15.80
SE	*0.125*	*0.24*	*0.45*	*0.1*	*0.11*

Table 1.2: Mineral nutrition profiles of fruit at harvest

Orchard	K	Ca	P	B	K/Ca	Predicted storage duration
39	118	14.0	11.8	1.3	8.4	Long-term
40	130	14.9	11.6	1.5	8.7	Long-term

All valuses are based on mg $100g^{-1}$ except boron (mg kg^{-1})

Table 2. Ex-store green colour (Minolta - a value, in L, a b mode) of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 ppb and 321 ppb)

Green colour		3 months	6 months	9 months	3 months	6 months	9 months
			Orchard			Orchard	
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	-8.6	-13.0	-8.0	-10.1	-11.2	-8.7
SF 625 ppb	1.5-2.0°C	-9.0	-10.2	-7.5	-12.0	-10.3	-9.1
SF 312ppb	1.5-2.0°C	-10.9	-8.3	-9.8	-11.1	-8.8	-8.7
Control	0.5-1.0°C	**-13.7**	-12.7	**-11.4**	**-14.9**	-10.5	**-12.1**
SF 625 ppb	0.5-1.0°C	**-14.2**	-11.4	**-14.1**	**-14.4**	-12.3	**-12.6**
SF 312ppb	0.5-1.0°C	**-14.4**	**-11.3**	-11.7	**-13.3**	**-11.2**	-11.5
Control	-1.0 to -0.5°C	**-14.6**	-13.5	**-14.7**	**-15.0**	-12.4	**-13.6**
SF 625 ppb	-1.0 to -0.5°C	**-14.3**	**-12.7**	**-13.4**	**-14.4**	**-13.2**	**-13.2**
SF 312ppb	-1.0 to -0.5°C	**-13.8**	**-12.6**	**-13.1**	**-14.7**	**-12.6**	**-12.3**

$LSD_{0.05}$ for the interaction between treatment x temperature x inspection =1.64 on 54df

Table 3. Ex-store Firmness (N) of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 321 ppb)

Firmness		3 months	6 months	9 months	3 months	6 months	9 months
			Orchard			Orchard	
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	60	51	43	63	54	46
SF 625 ppb	1.5-2.0°C	58	48	45	63	54	51
SF 312ppb	1.5-2.0°C	59	45	45	60	52	45
Control	0.5-1.0°C	62	**57**	**52**	62	**56**	**54**
SF 625 ppb	0.5-1.0°C	58	**55**	**54**	63	**57**	**58**
SF 312ppb	0.5-1.0°C	60	53	**52**	60	55	**55**
Control	-1.0 to -0.5°C	**66**	**58**	**59**	65	**61**	**61**
SF 625 ppb	-1.0 to -0.5°C	**63**	**57**	**57**	65	**61**	**60**
SF 312ppb	-1.0 to -0.5°C	**63**	58	**60**	**64**	60	**58**

$LSD_{0.05}$ for the interaction between treatment x temperature x inspection =2.72 on 54df

Divide by firmness values by 9.96 for conversion of Newtons to kg pressure

Table 4. Ex-store % rotting of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 321 ppb)

% Rots		3 months	6 months	9 months	3 months	6 months	9 months
			Orchard			Orchard	
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	0	5	6.6	0	0	5.8
SF 625 ppb	1.5-2.0°C	0	10	2.7	0	10	3
SF 312ppb	1.5-2.0°C	0	10	10	5	10	0
Control	0.5-1.0°C	0	0	0	5	5	3.2
SF 625 ppb	0.5-1.0°C	0	15	1.5	0	0	0
SF 312ppb	0.5-1.0°C	0	5	2	0	0	3.9
Control	-1.0 to -0.5°C	0	5	3.8	0	0	2.2
SF 625 ppb	-1.0 to -0.5°C	0	10	2.6	0	5	5.3
SF 312ppb	-1.0 to -0.5°C	0	5	3.2	0	0	0.8

LSD_{05} for the interaction between treatment x temperature x inspection =6.32 on 54 d

Table 5. Ex-store %Brix of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 321 ppb).

% Brix		3 months	6 months	9 months	3 months	6 months	9 months
		Orchard			Orchard		
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	13.4	12.7	12.8	13.1	12.4	12.5
SF 625 ppb	1.5-2.0°C	13.4	13.6	12.8	13.2	13.0	12.4
SF 312ppb	1.5-2.0°C	13.4	13.3	12.3	13.3	12.7	12.4
Control	0.5-1.0°C	13.5	12.8	13.0	12.7	13.1	12.3
SF 625 ppb	0.5-1.0°C	13.4	13.6	12.9	13.1	13.4	12.8
SF 312ppb	0.5-1.0°C	13.6	13.7	13.2	13.3	12.9	12.7
Control	-1.0 to -0.5°C	12.9	14.1	13.0	12.8	13.0	12.6
SF 625 ppb	-1.0 to -0.5°C	13.0	13.8	13.4	12.6	13.3	13.5
SF 312ppb	-1.0 to -0.5°C	13.4	13.6	13.3	13.0	13.1	13.2

$LSD_{0.05}$ for the interaction between treatment x temperature x inspection =0.455 on 54 df

Table 6. Ex-store % CO_2-injury of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 321 ppb).

% CO_2 - injury		3 months	6 months	9 months	3 months	6 months	9 months
		Orchard			Orchard		
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	0	0	25	0	0	10
SF 625 ppb	1.5-2.0°C	0	0	5	0	0	10
SF 312ppb	1.5-2.0°C	0	0	10	0	0	10
Control	0.5-1.0°C	0	0	0	0	0	0
SF 625 ppb	0.5-1.0°C	0	0	0	0	0	0
SF 312ppb	0.5-1.0°C	0	0	0	0	0	0
Control	-1.0 to -0.5°C	0	0	0	0	0	0
SF 625	-1.0 to -	0	0	0	0	0	0

ppb	0.5°C						
SF 312ppb	-1.0 to -0.5°C	0	0	0	0	0	5

$LSD_{0.05}$ for the interaction between treatment x temperature and inspection =5.95 on 54 df

Table 7. Ex-store % Shrivel of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 321 ppb).

% Shrivel		3 months	6 months	9 months	3 months	6 months	9 months
			Orchard			Orchard	
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	0	0	10	0	5	10
SF 625 ppb	1.5-2.0°C	0	0	0	0	0	0
SF 312ppb	1.5-2.0°C	0	0	0	0	0	5
Control	0.5-1.0°C	0	0	0	0	5	0
SF 625 ppb	0.5-1.0°C	0	5	0	0	0	10
SF 312ppb	0.5-1.0°C	0	0	0	0	5	0
Control	-1.0 to -0.5°C	0	5	15	0	0	5
SF 625 ppb	-1.0 to -0.5°C	0	0	15	0	10	10
SF 312ppb	-1.0 to -0.5°C	0	0	10	0	5	0

$LSD_{0.05}$ for the interaction between treatment x temperature and inspection =6.39 on 54 df

Table 8.The number of days taken to reach an eating quality firmness of 15N (1.5 kg) during shelf-life (18°C).

Days to reach 1.5 kg		3 months	6 months	9 months	3 months	6 months	9 months
			Orchard			Orchard	
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	6	5	5.5	6	5	6
SF 625 ppb	1.5-2.0°C	7	5	5.5	7	5	6
SF 312ppb	1.5-2.0°C	6	5	5.5	6	5	6
Control	0.5-1.0°C	6	6	6	6	6	6.5
SF 625 ppb	0.5-1.0°C	6	6	6	6.5	6	7
SF 312ppb	0.5-1.0°C	6	6	6	7	6	7
Control	-1.0 to -0.5°C	6	6	7.5	6	6	7.5
SF 625 ppb	-1.0 to -0.5°C	7	7	7.5	6.5	8	7.5
SF 312ppb	-1.0 to -0.5°C	6	7	7.5	7	6	7.5

The following figures display the rate of fruit softening in shelf-life tests from each experimental regime

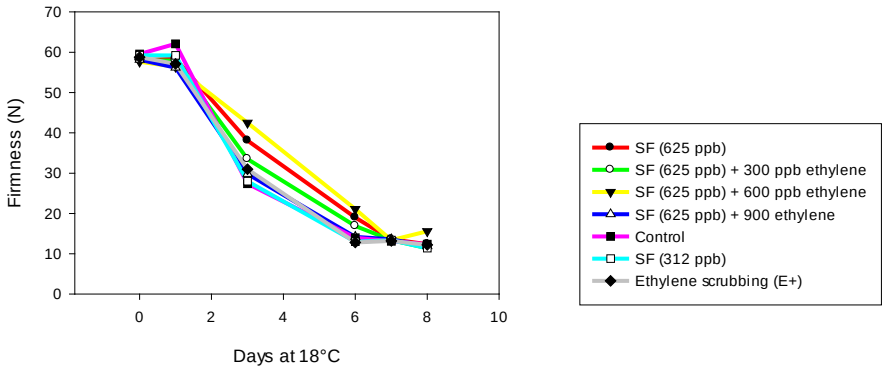

Fig 1.A CA storage of Conference pear (Orchard 39) for 3 months at 1.5-2.0°C

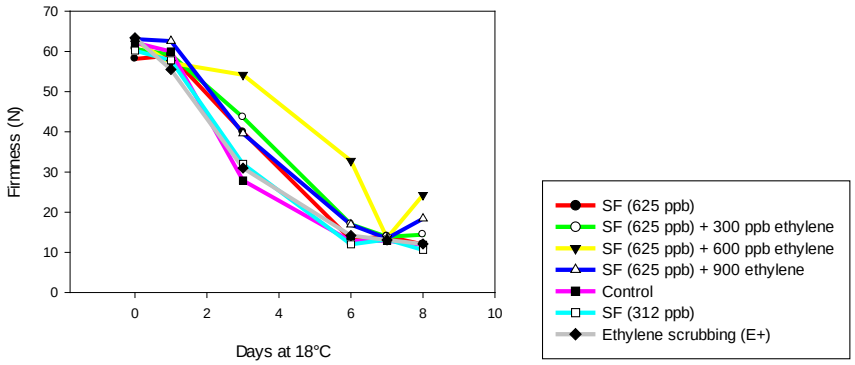

Fig 1.B CA storage of Conference pear (Orchard 39) for 3 months at 0.5-1.0°C

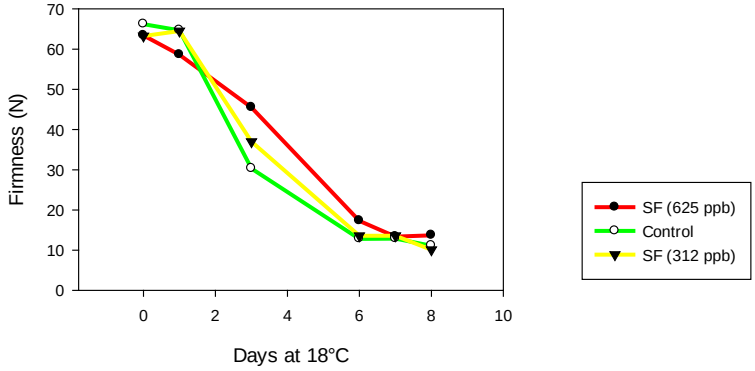

Fig 1.C CA storage of Conference pear (Orchard 39) for 3 months at -0.5 to -1.0°C

Figures 1A-C: Shelf-life softening curves for Conference pear (orchard 39) stored at for 3 months (2% O_2, <1.0% CO_2) either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C

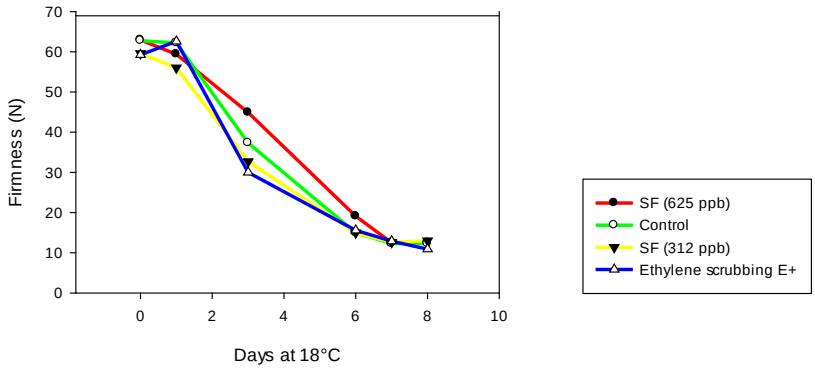

Fig 1.D CA storage of Conference pear (Orchard 40) for 3 months at 1.5-2.0°C

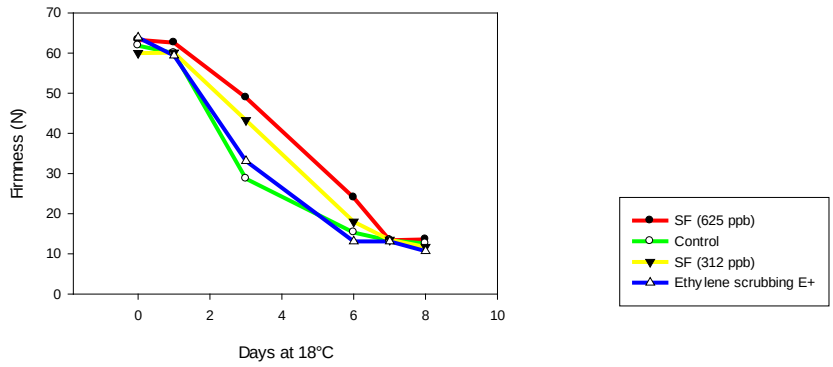

Fig 1.E CA storage of Conference pear (Orchard 40) for 3 months at 1.5-2.0°C

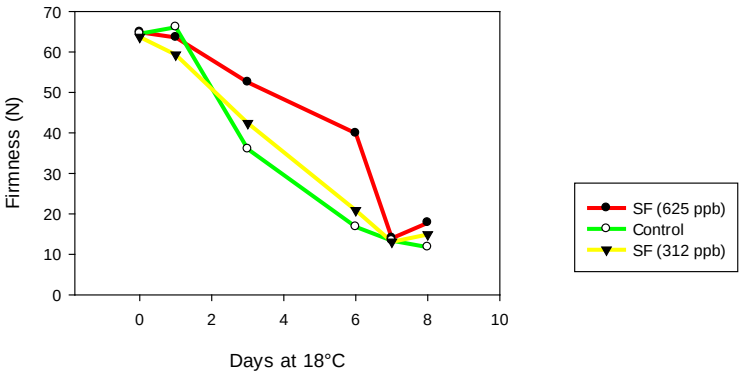

Fig 1.F CA storage of Conference pear (Orchard 40) for 3 months at -0.5 to -1.0°C

Figures 1D-F: Shelf-life softening curves for Conference pear (orchard 40) stored at for 3 months (2% O_2, <1.0% CO_2) either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C

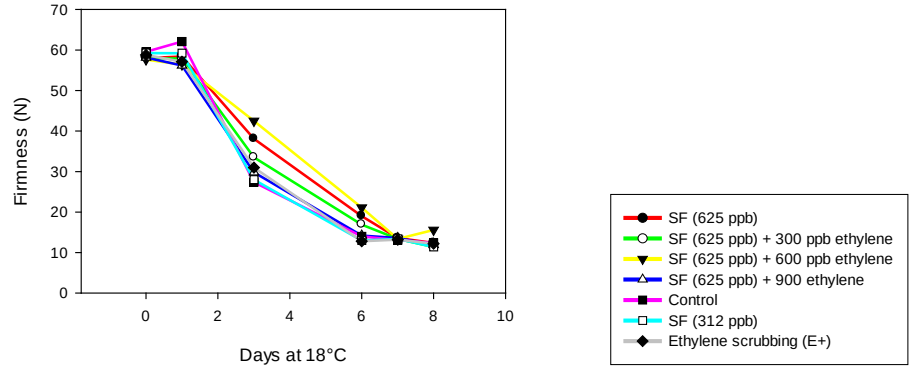

Fig 2.A CA storage of Conference pear (Orchard 39) for 6 months at 0.5-1.0°C

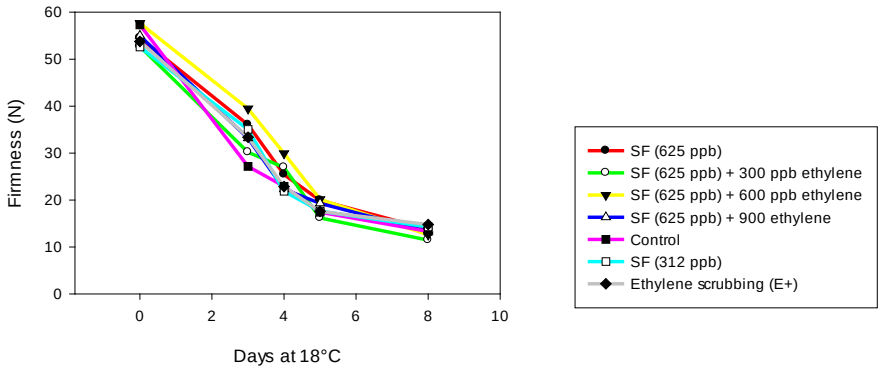

Fig 2.B CA storage of Conference pear (Orchard 39) for 6 months at 0.5-1.0°C

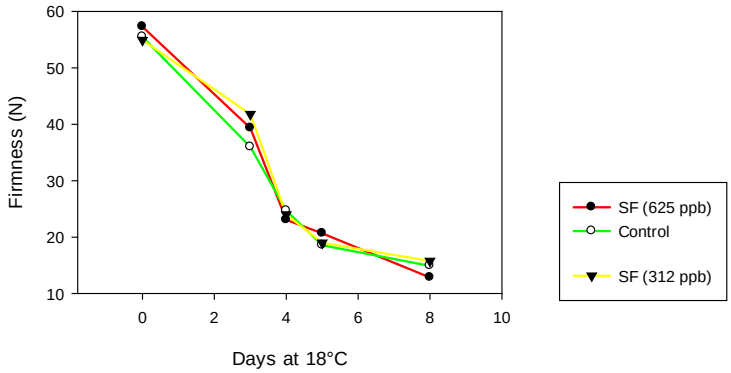

Fig 2.C CA storage of Conference pear (Orchard 39) for 6 months at -0.5 to -1.0°C

Figures 2A-C: Firmness of fruit during 8 days of shelf-life (18°C) for Conference pear (orchard 39) stored for 6 months at 2% O_2, <1.0% CO_2 at either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C.

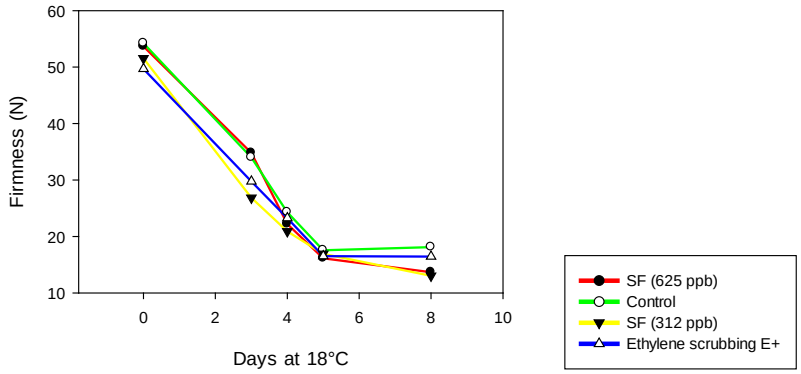

Fig 2.D CA storage of Conference pear (Orchard 40) for 6 months at 0.5-1.0°C

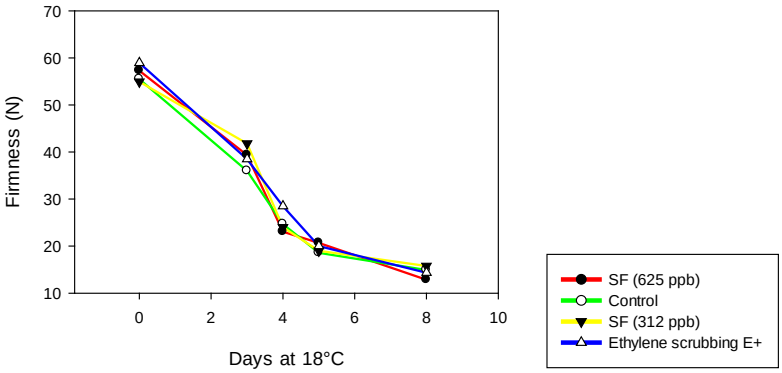

Fig 2.E CA storage of Conference pear (Orchard 40) for 6 months at 0.5-1.0°C

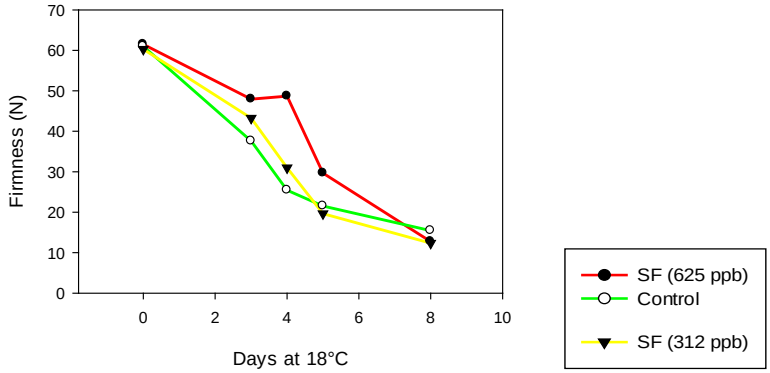

Fig 2.F CA storage of Conference pear (Orchard 40) for 6 months at -0.5 to -1.0°C

Figures 2D-F: Firmness of fruit during 8 days of shelf-life (18°C) for Conference pear (orchard 40) stored for 6 months at 2% O_2, <1.0% CO_2 at either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C.

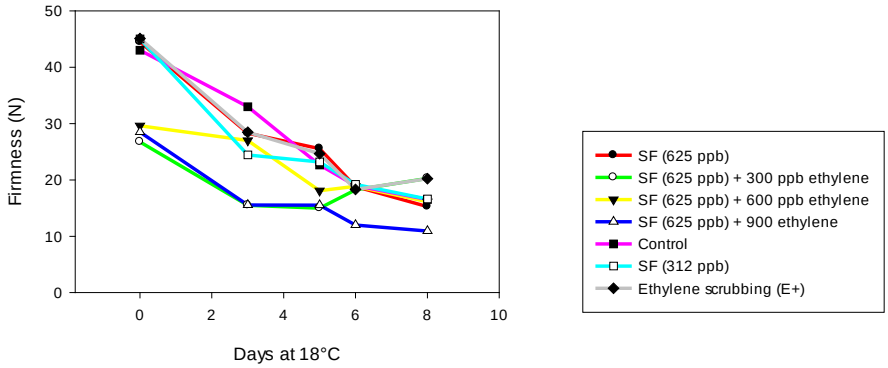

Fig 3.A CA storage of Conference pear (Orchard 39) for 9 months at 1.5-2.0°C

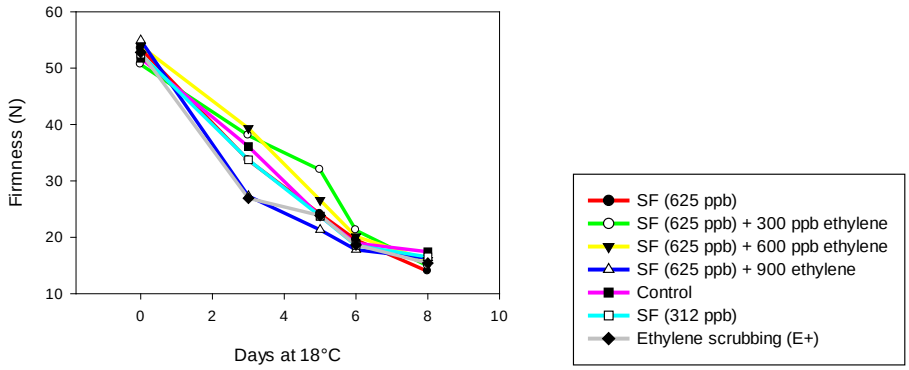

Fig 3.B CA storage of Conference pear (Orchard 39) for 9 months at 0.5-1.0°C

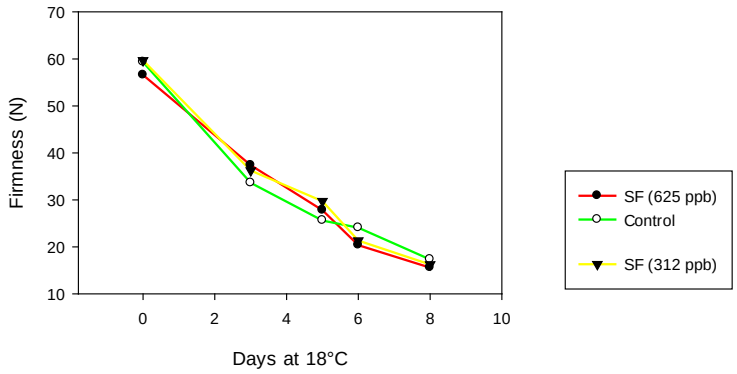

Fig 3.C CA storage of Conference pear (Orchard 39) for 9 months at -0.5 to -1.0°C

Figures 3A-C: Firmness of fruit during 8 days of shelf-life (18°C) for Conference pear (orchard 39) stored for 9 months at 2% O_2, <1.0% CO_2 at either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C.

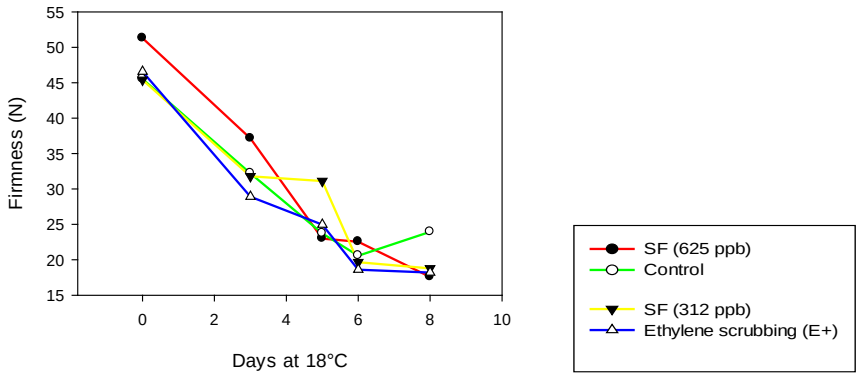

Fig 3.D CA storage of Conference pear (Orchard 40) for 9 months at 1.5-2.0°C

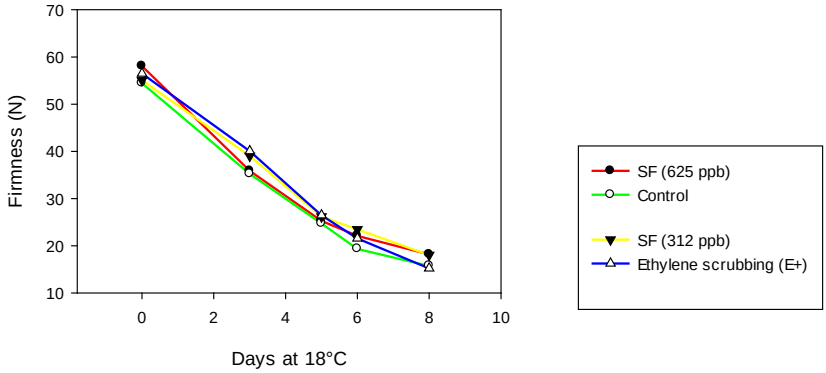

Fig 3.E CA storage of Conference pear (Orchard 40) for 9 months at 0.5-1.0°C

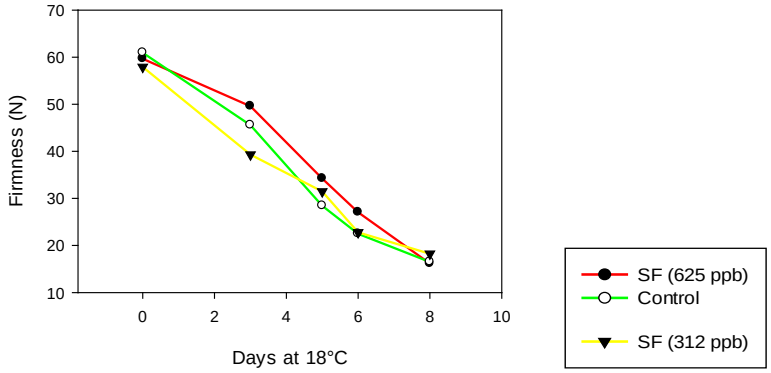

Fig 3.F CA storage of Conference pear (Orchard 40) for 9 months at -0.5 to -1.0°C

Figures 3D-F: Firmness of fruit during 8 days of shelf-life (18°C) for Conference pear (orchard 40) stored for 9 months at 2% O_2, <1.0% CO_2 at either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C.

Table 8. Quality parameters, rots and physiological injury for Conference pears stored for 9 months over a range of storage protocols

			Fruit	Minolta Colour Readings (Lab mode)						Max. Load		% SS				CO2 injury		Breakdown	
	Treatment	Orchard	No.	L	SE	A	SE	B	SE	Firmness(N)	SE	Brix	SE	% rots	SE	%	SE	%	SE
1.5-2.0°C	Full S/F	39A	10	65.2	1.90	-7.5	0.33	45.2	0.43	44.5	0.61	12.8	0.2	2.65	1.45	5	5	0	0
	Full S/F	40A	10	62.2	2.16	-9.1	1.28	42.3	2.09	51.3	1.62	12.4	0.2	3	1.5	10	0	0	0
	Full S/F + 300pp	39A	10	64.6	0.70	-6.0	1.89	44.2	0.79	26.7	3.61	12.65	0.45	10.3	1.1	50	0	45	5
	Full S/F + 600pp	39A	10	64.6	1.82	-5.2	0.20	45.9	0.74	29.6	3.51	12.55	0.05	22.45	0.05	50	0	45	5
	Full S/F + 900pp	39A	10	64.4	1.39	-7.5	0.92	44.5	0.09	28.5	1.65	12	0.1	11.05	6.75	45	5	35	5
	Control	39A	10	64.9	0.41	-8.0	0.11	44.2	0.18	43.0	1.10	12.75	0.05	6.55	3.95	25	15	0	0
	Control	40A	10	63.6	3.38	-8.7	1.00	43.3	1.27	45.5	0.80	12.45	0.05	5.75	2.95	10	10	0	0
	½ S/F	39A	10	63.0	2.51	-9.8	1.27	43.7	1.71	45.0	3.34	12.25	0.05	10	7.5	10	10	5	5
	½ S/F	40A	10	65.8	1.58	-8.7	0.00	45.5	0.78	45.4	1.42	12.35	0.15	0	0	10	0	0	0
	E+	39A	10	65.2	1.72	-7.0	0.96	45.0	0.37	45.1	1.92	12.65	0.05	1.9	0.7	0	0	0	0
	E+	40A	10	63.4	0.99	-9.5	0.61	44.3	0.99	46.6	0.97	12.2	0.1	4.1	0.8	0	0	0	0
0.5-1.0°C	Full S/F	39A	10	60.4	1.03	-14.1	0.80	41.2	0.71	53.5	0.81	12.9	0.3	1.45	1.45	0	0	0	0
	Full S/F	40A	10	60.5	0.19	-12.6	0.70	40.8	0.19	58.1	0.55	12.75	0.15	0	0	0	0	0	0
	Full S/F + 300pp	39A	10	58.7	0.81	-12.1	1.83	40.4	0.67	50.6	3.27	13.15	0.45	5.95	3.35	0	0	0	0
	Full S/F + 600pp	39A	10	59.2	1.65	-12.7	0.23	40.4	0.63	53.9	3.14	13.05	0.35	3.9	0.1	0	0	0	0
	Full S/F + 900pp	39A	10	61.8	0.47	-12.5	1.07	41.7	0.71	54.9	0.88	12.4	0.2	1.95	0.75	0	0	0	0
	Control	39A	10	63.1	0.60	-11.4	0.31	42.9	0.72	51.8	1.03	12.95	0.25	0	0	0	0	0	0
	Control	40A	10	62.4	0.65	-12.1	0.27	42.6	0.15	54.4	0.32	12.3	0	3.15	0.15	0	0	0	0
	½ S/F	39A	10	64.1	0.66	-11.7	2.21	43.1	1.10	52.5	2.35	13.2	0.3	2	0.7	0	0	0	0
	½ S/F	40A	10	62.1	1.30	-11.5	1.29	42.6	0.71	55.1	1.00	12.65	0.25	3.9	2.4	0	0	0	0
	E+	39A	10	61.4	0.53	-11.0	1.38	42.4	0.39	52.8	0.66	13.05	0.05	2.4	0	0	0	0	0
	E+	40A	10	57.9	1.29	-11.9	0.00	40.5	0.85	56.5	1.15	12.4	0.3	8.05	1.75	5	5	0	0
-0.5 -1.0°C	Full S/F	39A	10	58.4	1.55	-13.4	0.30	39.4	0.68	56.6	2.01	13.4	0.4	2.55	2.55	0	0	0	0
	Full S/F	40A	10	57.6	0.41	-13.2	0.22	39.9	0.12	59.7	1.30	13.45	0.05	5.3	0.4	0	0	0	0
	Control	39A	10	58.6	0.38	-14.7	0.05	39.3	0.37	59.3	0.52	12.95	0.15	3.8	2.5	0	0	0	0
	Control	40A	10	56.4	1.25	-13.6	0.48	37.8	0.67	60.9	1.15	12.6	0.3	2.2	0.7	0	0	0	0
	½ S/F	39A	10	57.1	1.00	-13.1	1.04	39.2	0.04	59.7	2.61	13.25	0.05	3.2	1.9	0	0	0	0
	½ S/F	40A	10	58.2	1.01	-12.3	0.13	39.9	0.38	57.9	0.07	13.2	0.3	0.75	0.75	5	5	0	0

Discussion and conclusions

From the results of the 2011-2012 season, extending the storage period for Conference pear beyond the existing 6-month window is most likely to be achieved through storing pears at standard temperatures. The effectiveness of SmartFresh™ was in-part due to orchard consignment. Both orchards had similar harvest maturity profiles based on firmness and sugars starch clearance. Moreover, mineral nutrition data and dry matter content of fruit was similar and suggested that fruit from both orchards was suitable for long-term storage. The fact that pear consignments from adjacent orchards and similar harvest maturities softened at different rates during storage and through shelf-life suggests that the time taken to reach an acceptable eating quality for SmartFresh™-treated pears may vary between orchard consignments.

The 2011 growing season was a particularly early season with early flowering combined with a warm dry summer. This led to fruits maturing two weeks earlier than the long-term average. The unusual growing season in the first year of the trial may have resulted in fruit with poor storage characteristics.

The limited effect of SmartFresh™ on suppression of softening during storage may be linked to the high incidence of rotting in storage containers which was particularly problematic at higher storage temperatures. The presence of high numbers of rotting pears elevated the ethylene concentration within the storage atmosphere and accelerated the rate of softening, which undermined the benefit of SmartFresh™. With the elevated ethylene concentrations in the storage containers it was not possible to determine the potential benefit of adding small doses of ethylene to the storage atmosphere at the point of SmartFresh™ application. This will be investigated further in the second year of the trial.

In conclusion, storage of Conference pear at 1.5-2.0°C is not recommended as an alternative storage treatment for SmartFresh treated pears because of the high rate of rotting associated with storing pears at higher temperatures.

The possibility of storing SmartFresh-treated pears at 0.5-1.0°C or storing fruit at standard storage temperatures with a half-rate treatment (312 ppb) is being investigated in the second year of this trial in Conference pears selected from a wider range of orchards and over several picking dates.

Knowledge and technology transfer

This project was presented at the EMRA Storage Day in March 2012.