The impact of harvest maturity and cold storage duration on superficial scald development on Granny Smith apples

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INTRODUCTION

Prohibition of the use of Diphenylamine (DPA) to control the development of superficial scald on susceptible apple cultivars intended for export to certain markets has created quite a complicated challenge. After many years of relying on DPA, suddenly we need to seek additional alternatives. Even if DPA is used on apples destined for markets where DPA residues are still accepted, the risk of cross contamination from bins and paint in cold rooms to untreated fruit makes already complicated marketing strategies even more complicated. Evidence has recently indicated that levels as high as 0.48 mg/kg may be found on untreated fruit, which far exceeds the new MRL of 0.1 mg/kg. Another major source of contamination may come from storing untreated fruit such as Forelle pears; in cold stores containing DPA treated apple cultivars.

At present, a frequently asked question is whether or not superficial scald development on cold stored Granny Smith apples can be avoided by harvesting at specific maturities. To try and answer this question, we delved into research reports reaching back to the 2000 fruit season.

Initially, this research was conducted on the premise that to effectively manage post-harvest fruit quality, it would be beneficial to compile a detailed fruit physiological profile for each commercial cultivar. The physiological profiling involved harvesting fruit at different maturities, and storing for different durations, to establish how the internal and external quality characteristics of the fruit were affected by these factors. In 2000, ExperiCo, or Capespan Technology Development, as the unit was then known, was also commissioned by AgroFresh Inc. to do registration trials for SmartFresh^{SM} (1-MCP or 1-methylcylopropene) on apples and pears. While the main emphasis of this research was on maintaining fruit quality during extended storage durations and shelf-life, one of the most profound physiological responses of this product was to inhibit and control superficial scald development.

To facilitate easy reading, the summary of research is presented directly below, with the support data provided thereafter, to enable readers to draw own conclusions. In this communication, the fruit quality results generated from physiological profiling and SmartFresh^{SM} trials on Granny Smith apples are presented and summarised with particular emphasis on superficial scald control.

SUMMARY OF RESEARCH AND FACTORS TO CONSIDER IN A NON DPA ENVIRONMENT

Several clear trends and conclusions were evident. First, is that as generally known, pre-optimum maturity Granny Smith apples are more prone to superficial scald development than fruit harvested in the optimum maturity window or later. It was also obvious that fruit harvested at a more advanced maturity are not immune to the disorder, although the incidence is generally lower than for earlier harvests. Second, is that superficial scald incidence increases with longer storage durations. Initial studies indicated that no scald development occurs before 8 weeks cold storage under regular atmosphere storage. However, the unpredictability of this disorder was observed in a study in 2005, when fruit harvested at post optimum maturity with a starch conversion in excess of 60% exhibited over 80% scald after only 8 weeks storage. Another study in 2010 revealed somewhat different results, when pre-optimum maturity fruit, with less than 10% starch conversion, stored for 12 weeks, did not develop superficial scald. Therefore, a storage period of 8 weeks may already be associated with increased risk of superficial scald development. Third, is that SmartFresh^{SM}, when applied within the recommended protocol of 7 days of harvest, can completely control superficial scald development over a wide maturity range of maturities for up to 9 months RA or CA cold storage plus a shelf-life. While not studied in great detail, a fourth trend observed was a reduction in the incidence of superficial scald when fruit were stored in the standard non-perforated apple bag.

The question is how this information can be used to assist in managing apple quality in a DPA free environment. As stated above, Granny Smith apples stored for more than 8 weeks may develop superficial scald. Hence, these results suggest that non-DPA treated fruit must be sold within 8 weeks of harvest. For markets which do not allow DPA, the only alternatives available to manage superficial scald, as far as we are aware, are SmartFresh^{SM}, and possibly Dynamic Controlled Atmosphere (DCA) storage. DCA forms part of the research programme conducted by Kobus van der Merwe at Infruitec. For further information on DCA research, readers will need to contact Kobus directly.

HARVEST MATURITY OF GRANNY SMITH APPLES

The main maturity indices used to release Granny Smith apple orchards are percentage starch conversion, seed colour, and malic acid equivalents. Pre-optimum maturity fruit can be harvested when an orchard is released at 20% starch conversion, with a seed colour of 4.5 (3/4 brown) on the seed colour chart, and a maximum acid level not exceeding 0.75%. Optimum maturity fruit are normally harvested between 30 and 50% starch conversion, a seed colour of 5.0 – 6.0, and an acid range between 0.60 and 0.55%. Fruit are post-optimum when starch conversion exceeds 50%, seed colour is 6.0 (fully brown), and when acids decrease below 0.50%. It is generally speculated that superficial scald potential lessens about 10 days after an orchard has been first released, which would be about 5 days into the optimum harvesting window.

1. PHYSIOLOGICAL PROFILING TRIAL

Granny Smith apples, sourced from a farm in Elgin, were harvested over three maturities, namely (H1, H2, and H3). Fruit were not subjected to DPA or SmartFresh^{SM}. Sub-samples of fruit harvested at each maturity were held in lug boxes for 7 days and then packed and cold stored under regular atmosphere (RA) for 5, 10 and 15 weeks at –0.5°C plus 3 days at 7.5°C (distribution) followed by a shelf-life period of 4 days at 15°C for each duration. No liner bags were utilised during cold storage. After cold storage plus the shelf-life period, the ripeness of the fruit, and incidence of disorders were determined.

Maturity indexing data indicated that the first harvest would have fallen just outside of the release criteria, whereas H2 and H3 fruit were harvested within the optimum range for export fruit (Table 1). Furthermore, as one would expect, the harvest maturity advanced the later the harvest. Of all the maturity parameters measured, this was most apparent from the starch conversion, seed colour and total soluble solids data. Over the 3 week harvest period, starch conversion progressed from approximately 18% to 43%, and seed colour from 3.8 to 5.8, while total soluble solids increased concomitantly from 9.8 to 11.2%.

Of particular relevance was that fruit stored for up to 10 weeks did not develop superficial scald, irrespective of harvest maturity (Figure 1). However, after 15 weeks of storage, Granny Smith apples across the maturity range of 17.8% to 42.8% starch conversion developed levels of superficial scald in excess of 80%. Therefore, despite slightly higher levels of scald in H1 fruit, apples across all the maturities tested in this study developed unacceptable levels of scald.

Table 1: Harvest maturity of Granny Smith apples sampled at three consecutive stages from a farm in Elgin

Maturity parameter	Harvest maturity stage		
	H1 (week 13)	H2 (week 14)	H3 (week 16)
Starch conversion (%)	17.8	32.5	42.8
Flesh firmness (kg)	8.1	7.7	7.7
Total soluble solids (%)	9.8	10.9	11.2
Titratable malic acid (%)	0.86	0.89	0.73
Skin colour (0.5 = green, 5.0 = yellow)	2.1	2.3	1.8
Seed colour (0.0 = white, 6.0 = fully brown)	3.8	4.9	5.8
Fruit diameter (mm)	70.3	74.6	70.4

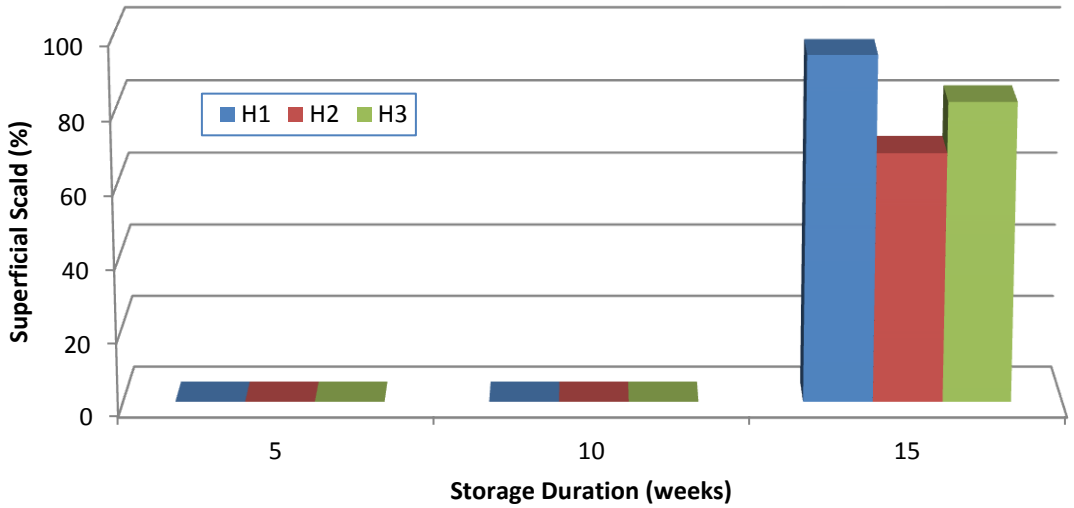

Figure 1: The effect of harvest maturity and storage duration on the incidence of superficial scald on Granny Smith apples sourced from a farm in Elgin and cold stored under regular atmosphere for 5, 10 and 15 weeks at –0.5°C plus 3 days at 7.5°C (distribution) followed by a shelf-life period of 4 days at 15°C for each duration.

2. SMARTFRESH^{SM} TRIALS

YEARS 2000 and 2001 – First observations of scald control following SmartFresh^{SM} application:

Granny Smith apples in the 2000 trial, were sourced from two harvest maturity populations, with a starch conversion of 33% (H1) and 43% (H2), and treated with SmartFresh^{SM} immediately after harvest. Fruit were cold stored under RA for 8, 16 and 24 weeks at –0.5°C followed by a shelf-life period of 7 days at 15°C. No liner bags were utilised during cold storage. The fruit were assessed for superficial scald after each cold storage period, and again after the shelf-life period. A DPA control was included in this trial.

SmartFresh^{SM} gave complete control of superficial scald for the full 24 weeks cold storage (Figure 2). H1 fruit treated with DPA did not develop scald for the duration of the trial, whereas H2 fruit treated with DPA exhibited some superficial scald after 16 weeks cold storage plus shelf life. Untreated control fruit were scald free for the first 8 weeks cold storage, including shelf-life. Superficial scald was first evident on control fruit following 16 weeks cold storage, regardless of harvest maturity, and at levels in excess of 60%.

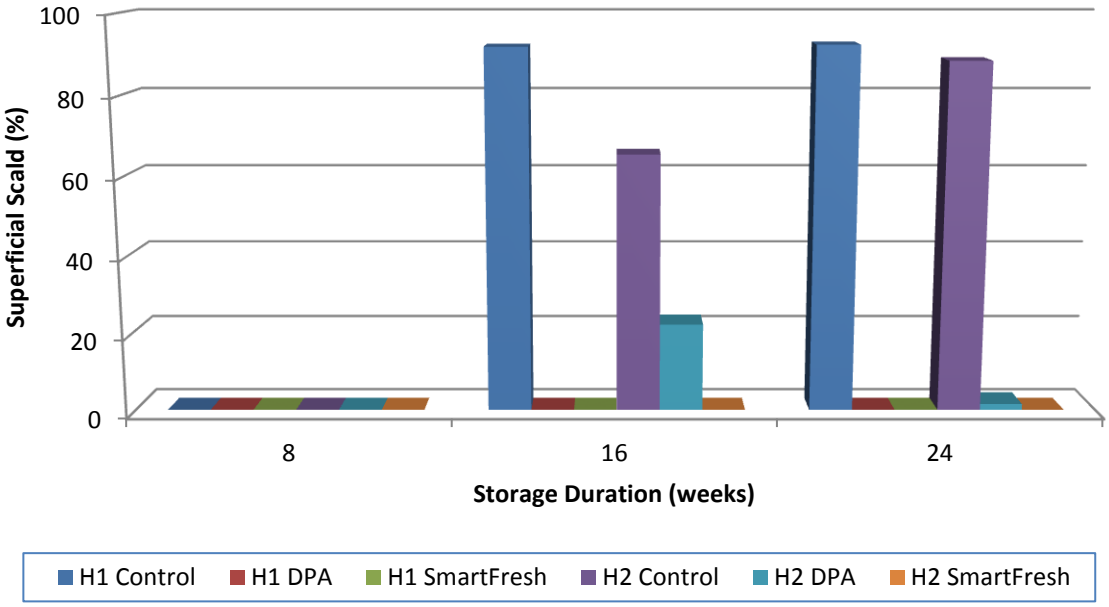

Figure 2: The effect of harvest maturity, DPA and SmartFresh[SM] on incidence of superficial scald on Granny Smith apples cold stored under regular atmosphere for 8, 16, or 24 weeks at -0.5°C followed by a shelf-life period of 7 days at 15°C

In 2001, Granny Smith apples, also sourced from a farm in Elgin, were harvested over two maturities (H1 and H2) (Table 2), and treated with SmartFresh[SM] immediately after harvest. Fruit were cold stored under regular atmosphere (RA) for 8, 16 and 24 weeks at –0.5°C followed by a shelf-life period of 7 days at 15°C. No liner bags were utilised during cold storage. The fruit were assessed for superficial scald after each cold storage period, and again after the shelf-life period. A DPA control was again included in this trial.

Maturity indexing data indicated that H1 fruit were pre-optimum maturity, whereas H2 fruit were on the border of the post-optimum window (starch conversion >50%) (Table 2). Over the 3 week harvest period, starch conversion progressed from approximately 21.3% to 55.5%, while titratable acidity decreased from 0.79% to 0.62%.

This trial confirmed the findings of the 2000 season. The SmartFresh[SM] treatment resulted in complete control of superficial scald in this trial for the full 24 weeks cold storage plus shelf-life (Figure 3). Fruit treated with DPA did not develop scald for the duration of the trial. Untreated fruit were scald free for the first 8 weeks cold storage, including shelf-life. Superficial scald was first evident on control fruit during the shelf-life period following 16 weeks cold storage, regardless of harvest maturity.

Table 2: Harvest maturity of Granny Smith apples sampled at two consecutive stages from a farm in Elgin

Maturity parameter	Harvest maturity stage	
	H1 (week 15)	H2 (week 18)
Starch conversion (%)	21.3	55.5
Flesh firmness (kg)	8.3	7.6
Total soluble solids (%)	12.1	12.6
Titratable malic acid (%)	0.79	0.62
Skin colour (0.5 = green, 5.0 = yellow)	1.9	1.9
Fruit diameter (mm)	72.9	73.1

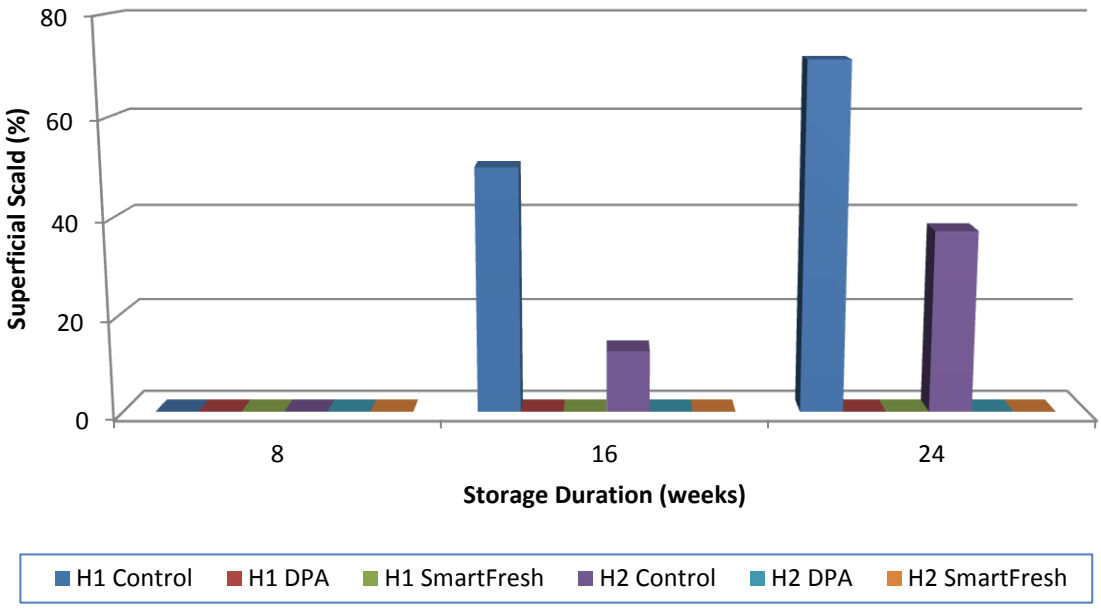

Figure 3: The effect of harvest maturity, DPA and SmartFresh^{SM} on incidence of superficial scald on Granny Smith apples cold stored under regular atmosphere for 8, 16, or 24 weeks at -0.5°C followed by a shelf-life period of 7 days at 15°C

YEAR 2002 – First commercial SmartFresh^{SM} application in South Africa

During 2000 and 2001, Granny Smith apples were treated with SmartFresh^{SM} on a laboratory scale. Results from these trials indicated that SmartFresh^{SM} was effective in the total control of superficial scald development, providing an alternative treatment to DPA drenching. The data presented below is from the first commercial room application of SmartFresh^{SM} on apples in South Africa, with fruit sourced from the treated room after controlled atmosphere (CA) and RA storage.

Granny Smith apples, sourced from Ceres during Week 18 with an average flesh firmness of 7.3 kg, green skin colour of 2.3, fruit size of 74.1 mm, TSS of 11.8%, malic acid of 0.23% and starch

conversion of 53.8 % were subjected to SmartFresh^{SM} within 7 days of harvest. Half the fruit were placed under CA and the balance under RA. Samples were packed into cartons after 0, 2, 4, 6, and 8 months under RA conditions and 4 and 8 months under CA conditions. Thereafter, a further 4 weeks RA at –0.5°C, followed by a "simulated distribution" period of 3 days at 7.5°C and a shelf life period of 4 days at 15°C was employed. No liner bags were utilised during cold storage. The fruit were assessed for superficial scald after each cold storage period, and again after the shelf-life period. A DPA control was included in this trial.

Maturity indexing data indicated that fruit were just within the post optimum window (starch conversion >50% and titratable acidity only 0.23%), and so had a supposedly low superficial scald potential.

SmartFresh^{SM} and DPA treatments resulted in complete control of superficial scald for the full 36 weeks (8 months + 4 weeks in carton) cold storage plus shelf-life (Figure 4). Untreated fruit first exhibited scald after 12 weeks cold storage, including shelf-life. Thereafter, levels steadily increased with increasing storage duration. Although storing the fruit under CA conditions reduced the incidence of scald development, levels were still commercially unacceptable.

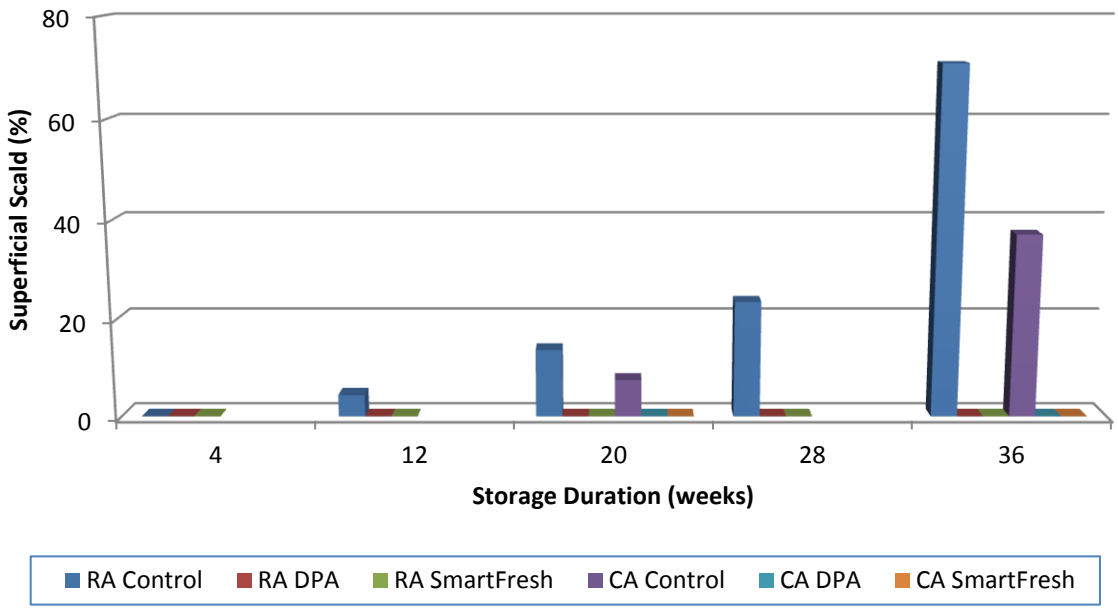

Figure 4: The effect of DPA and SmartFresh^{SM} on incidence of superficial scald on Granny Smith apples cold stored under regular atmosphere or controlled atmosphere conditions for up to 36 weeks

YEAR 2005 – Effect of apple liner bags and SmartFresh[SM] application on superficial scald incidence

During the 2005 season, ExperiCo studied the application of SmartFresh[SM] on packed cartons of Granny Smith apples intended for shorter term storage duration. Granny Smith apples were sourced from Elgin during Week 15, with an average flesh firmness of 7.2 kg, green skin colour of 1.8, TSS of 11.8%, malic acid of 0.65% and starch conversion of 60.5%. Fruit were subjected to SmartFresh[SM] within 7 days of harvest and stored for 8 weeks RA at –0.5°C, followed by a shelf life period of 7 days at 15°C at which time fruit were assessed for superficial scald.

Maturity indexing data indicated that fruit had an advanced maturity (starch conversion >60%) and so had a relatively low superficial scald potential.

The SmartFresh[SM] treatment resulted in complete control of superficial scald for the full 8 weeks cold storage plus shelf-life examinations (Figure 5). Untreated control fruit exhibited 2.3% scald directly after 8 weeks cold storage, which increased to over 80% during shelf-life. Storing untreated fruit in a standard industry apple bag reduced scald levels after shelf-life to 22.8%, although this was not the case for all bag types tested (Crouch et al., 2011). Of particular concern was that over 80% scald developed in this population of post-optimum Granny Smith apples, stored for only 8 weeks.

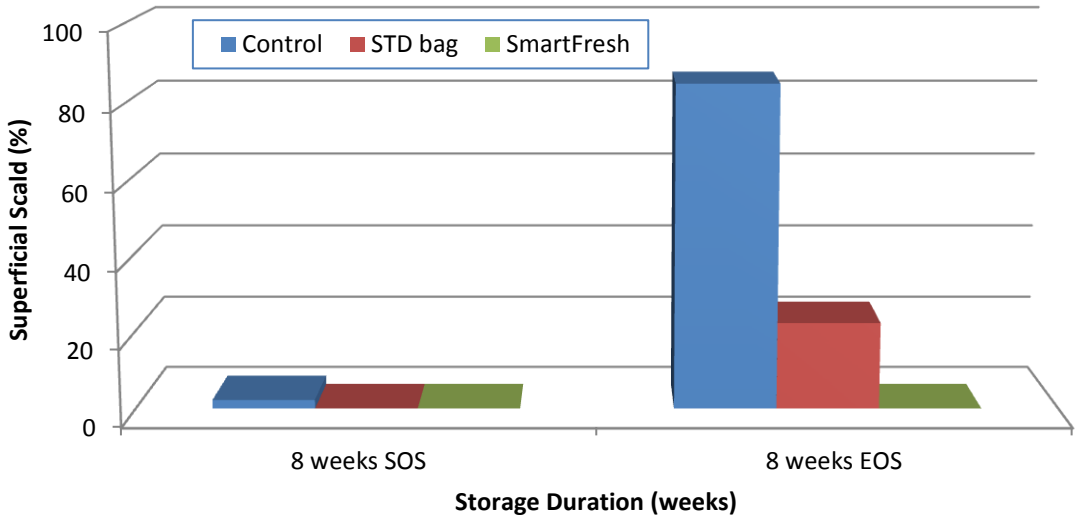

Figure 5: The effect of the standard apple bag and SmartFresh[SM] on incidence of superficial scald on Granny Smith apples cold stored under regular atmosphere for 8 weeks at -0.5°C followed by a shelf-life period of 7 days at 15°C

YEAR 2008 – Effect of delayed SmartFresh[SM] application on superficial scald development

In 2008, a trial was commissioned by AgroFresh Inc. to determine the effect of delayed SmartFresh[SM] application on the control of superficial scald. In some instances, the filling of cold stores may take longer than the recommended 7 days after harvest protocol, and so this research was conducted to determine how important and strict this protocol should be.

Apples were sourced at six different maturities from week 15 to week 20. SmartFresh[SM] was applied to each harvest after 1, 4, 7 and 14 days for approximately 24 hours and then the fruit were packed into MK VI cartons. Fruit were stored for a total of 16 weeks at –0.5°C, with the last four weeks in 37.5 micron liner bags. The apples were examined at the end of this cold storage period and again after a shelf-life of 7 days at 20°C. The first harvest was in week 15 (± 25% starch conversion), and fruit were harvested weekly over 5 weeks until week 20 (± 70% starch conversion) (Table 3). Flesh firmness, TSS and acid levels indicated progressive fruit maturation over time.

Maturity indexing data indicated that all fruit were within the optimum harvest window (starch conversion <50%), apart from the last harvest which was picked at a post-optimum maturity. After 16 weeks cold storage plus a shelf life period, superficial scald incidence was highest in the early harvested control fruit (>65%), with levels declining as fruit were harvested at more advanced maturities (Figure 6). SmartFresh[SM], applied within seven days, exhibited acceptable scald control, whereas when applied after 14 days it was not effective in preventing this disorder on optimum maturity fruit. Incidence and severity of superficial scald in this late treated fruit were, however, less than in untreated fruit. This data indicated the importance of applying SmartFresh[SM] to fruit as soon after harvest as possible and led to the practice of treating all fruit within 7 days, even if this meant a half room application within 7 days, followed by a second application to the full room within an additional 7 days.

Table 3: Harvest maturity of Granny Smith apples sampled at six consecutive stages from a farm located in Elgin

Maturity parameter	Harvest maturity stage					
	H1 (wk 15)	H2 (wk 16)	H3 (wk 17)	H4 (wk 18)	H5 (wk 19)	H6 (wk 20)
Starch conversion (%)	24.5	37.2	33.0	46.9	42.1	72.3
Flesh firmness (kg)	7.8	7.5	7.4	7.2	7.0	7.0
Total soluble solids (%)	10.5	11.2	11.2	11.3	11.2	11.5
Titratable malic acid (%)	0.56	0.55	0.54	0.51	0.51	0.44

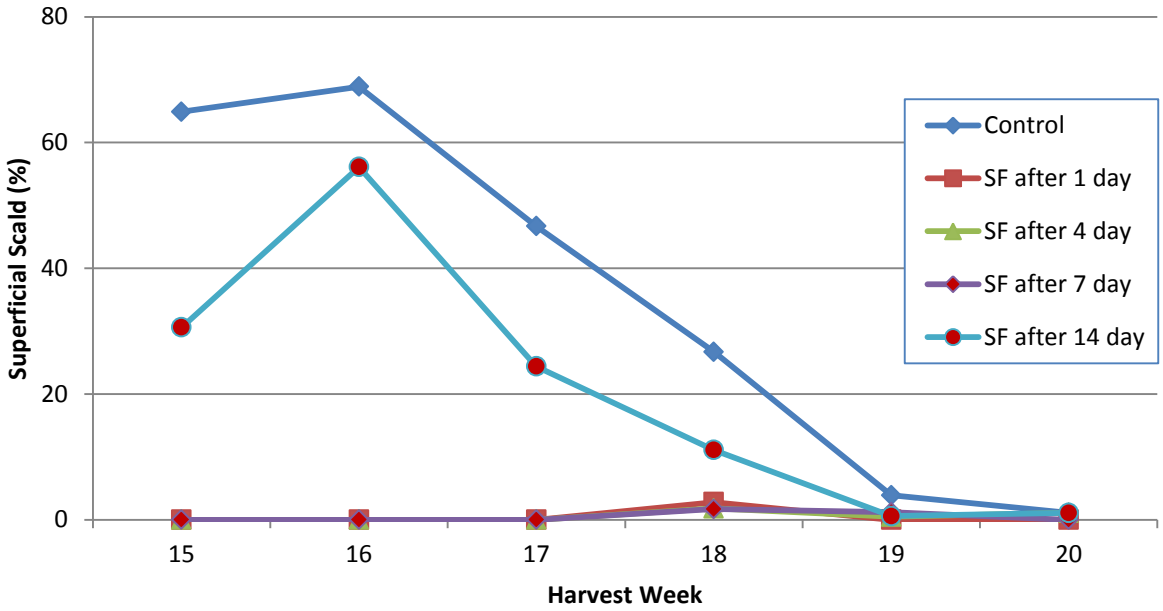

Figure 6: The effect of the harvest maturity and SmartFresh[SM] application time on the incidence of superficial scald on Granny Smith apples cold stored under regular atmosphere for 16 weeks at -0.5°C followed by a shelf-life period of 7 days at 15°C

YEAR 2010 – Unpredictability of superficial scald development

In 2010, an additional trial was commissioned by AgroFresh Inc. to determine the effect of harvest maturity of Granny Smith apples on SmartFresh[SM] application efficacy. Although fruit were harvested from across a wide range of maturities, as low as 7.2% starch conversion, no superficial scald developed during the 12 weeks storage, regardless of treatment. This trial indicated the unpredictability of this disorder, as scald would have been expected at this stage, especially in the pre-optimum maturity fruit.

REFERENCE

Crouch, I., Bergman, H. and Viljoen, H. 2011. Efficacy of SmartFresh[SM] applications to palletised cartons of apples. SA Fruit Journal, 10(2): 39-41