Future Orchards 2012

Harvest maturity

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1. Harvest maturity basics

Apples are complex objects and react in a whole range of ways to different seasons and different management. Because no two years are ever exactly the same, the fruit at harvest time will never behave or appear exactly the same! Predicting optimum harvest dates is complex and there are a whole range of indicators to judge maturity by.

Fruit destined for fresh market, short-term storage and long-term storage all have different optimum picking requirements. Sometimes you don't know how long you will keep fruit and this adds another layer of complexity. The aim is to pick fruit so it will taste its best when in the hands of the consumer. Fruit is alive – but slowly dying – and its characteristics are not static. You have to know the characteristics of the fruit, then juggle the storage facilities and skills you have and the vagaries of the market. Not easy.

I've listed overleaf 10 of the most common methods to judge apple maturity. If we are trying to run a semi-scientific system obviously 10 is too many indicators!

If the destination of my fruit was fresh market I would use skin colour, sugar and pressure in that order.

If the destination was storage I would add in <u>starch</u> at the front of the list and relegate skin colour to the fourth factor. The conversion of starch to sugar is the leading edge indicator of many ripening processes and is something you can measure that will tell you an apple's physiological age before anything else.

Also if the destination was storage I shift pressure to just behind starch so that the list of preferred indicators is; starch, pressure, sugar and skin colour.

Pressure is something that we know will decline in storage and is actually part of consumer's 'perceived taste'. Taste is the word the consumer uses to rate an apple. Taste obviously encompasses sugar, starch and acid but texture (pressure) is also a big component of perceived taste. Taste panels can easily section off the texture component of an apple's 'taste'. Our experience tells use that firm apples with just average sugar/acid will always outsell soft apples with excellent taste. The chain stores know this and that's why pressure is usually a major specification.

The underlying assumption for any stored fruit is that disorders must be minimized. Superficial scald is a major disorder that can develop if immature fruit is harvested and stored for too long. Internal browning in Pink Ladys and Sundowners is a disorder associated with over mature fruit.

Method	Comment
Skin colour	Market channels wish to maximise colour, some consumers also do. Can hide a lot of sins (small marks and bruises). Fairly unreliable maturity indicator. Can be greatly affected by weather and management.
Background colour	A good indicator of over maturity.
Starch	Very good indicator of storage suitability. Can be easily measured.
Pressure	A good indicator. Can be easily measured.
Seed colour	A reasonable indicator when used in conjunction with starch, sugar and pressure. Variable and unreliable in some years.
Ethylene production	Was once considered to have potential but difficult to measure. May be an indicator that fruit is over-mature.
Sugar	Very important for consumers. Can be easily measured.
Acid	Very important for consumers. Not so easily measured.
Taste	Very important for consumers. Not so easily measured.
Calender or schedule	Worst method available In reality what is sometimes used when pushed for harvest labour

The climates in most of the Australian apple growing districts are challenging and our variety mix is also unique, so the yardsticks developed overseas cannot be simply transplanted. However in Australia we have been fortunate to have some very good post-harvest researchers and technicians solving problems over a number of years. The book that everyone should have is "*Storage Technology for Apples and Pears*", the green covered book by Colin Little and Robert Holmes published by the Victorian Dept of Natural Resources and Environment in 2000. It was produced with APAL and HRDC funding assistance and has over 500 pages of excellent information, some of which I will reference directly to in this paper.

Measuring starch

Read about this on pages 132 and 147-149 of the green book. It works best as an indicator on varieties that have high starch levels – which is most modern varieties. Jonathan, Gala and Fuji have low starch levels when they are at their best harvest maturity, so it is a less important an indicator in these varieties.

Traditionally apples have been cut in half and placed in a shallow container containing 5mm of iodine for 30 seconds then removed and rated for colour after 45 seconds. If you are doing a number of samples this can take up a lot of table space and uses a lot of iodine solution per sample. A quicker more economical method is to cut the apples and place then face up on a pressed cardboard apple tray, and spray the iodine solution from a small hand-held, pump-action spray pack. Be sure to spray plenty of liquid on the fruit and let the colour develop over about a minute. Stray spray can stain things so spread newspaper on the bench first!

This system has the advantage of being able to be done in the field on the back of a utility vehicle without having to carry around dishes and bottles of iodine. The tested fruit can be discarded in the field.

The recipe for the iodine solution testing solution is on page 147 of the Little and Holmes green book. It is;

10 grams of potassium iodide + 1.5 grams iodine crystals in 1 litre of water.

The potassium iodide is readily available at local chemist shops, but the iodine crystals component has become difficult to buy as the chemical is restricted. The last time I purchased some it was from Biolab (Aust) Pty Ltd, Locked Bag 24, Mulgrave VIC 3170, (03) 9263 4446 www.biolabgroup.com. Some documentation was involved but I got 100 grams, which goes a long way.

It is important to keep the mixed solution out of direct sunlight as this degrades the solution. Wrap foil around your storage bottles, use a non-translucent spray-pack bottle or paint the bottle a dark colour.

Unfortunately there is a bit of a dog's breakfast when it comes to rating scales to interpret the degree of starch staining of apples. The 'number' is often referred to as the SPI = starch pattern index.

Rating system	Range	Comment
NSW Ag	0 to 6	Original scale
Washington scale	1 to 6	More recent and more popular. Used in Little and Holme's green book
European Scale	1 to 10	Also known as the CTILF scale
Canadian	1 to 9	

The optimum SPI for long term stored fruit varies for each apple variety. The green book lists the guidelines on page 144. AgroFresh has recently produced shed posters with pictures of stained fruit and recommendations based on the green book, and as most growers are now using Smartfresh for their longest stored fruit I will refer to those later in some 2008 case studies.

Measuring pressure

Read about this on pages 133-134 and 150-152 of the green book. Firmness varies depending on fruit size, variety and season and is not a good indicator of maturity for apples if used by itself. However if you look at the changes in firmness as you approach harvest and combine this with starch and sugar it tells a good story. If starch is a leading indicator of maturity then firmness is a lagging indicator.

The really important thing about firmness is that we know it will decline with storage and will decline in the marketing chain. We also know what the minimum pressure specifications are for chain store sales.

So at harvest you need to have a minimum firmness of ;

chain store spec + expected storage loss + expected marketing chain loss

Firmness can still be high in fruit that is forward (based on starch) but the firmness drops quicker on over-mature fruit. Using Smartfresh dramatically slows the softening of fruit during storage. Because of this Smartfresh is sometimes used as a 'rescue tool' in over mature fruit, although this is certainly not a guaranteed result.

Most growers have a hand held penetrometer and if you are not doing too many samples and are careful with your method this be suffice. The disadvantage of hand held penetrometers is that there is variation in the 'push' you give the device the readings for the sample apple will vary =/- up to a kilogram. Sampling more apples per sample will help even this out. It is not likely that you will over-estimate the firmness of a soft apple, but it is possible to under-estimate firmness.

Larger growers and many packing sheds now have automated equipment that is more precise and usually connected to a computer data logging device. For both hand held and automated penetrometers use the larger head (11mm) for apples and the smaller head (8 mm) for pears.

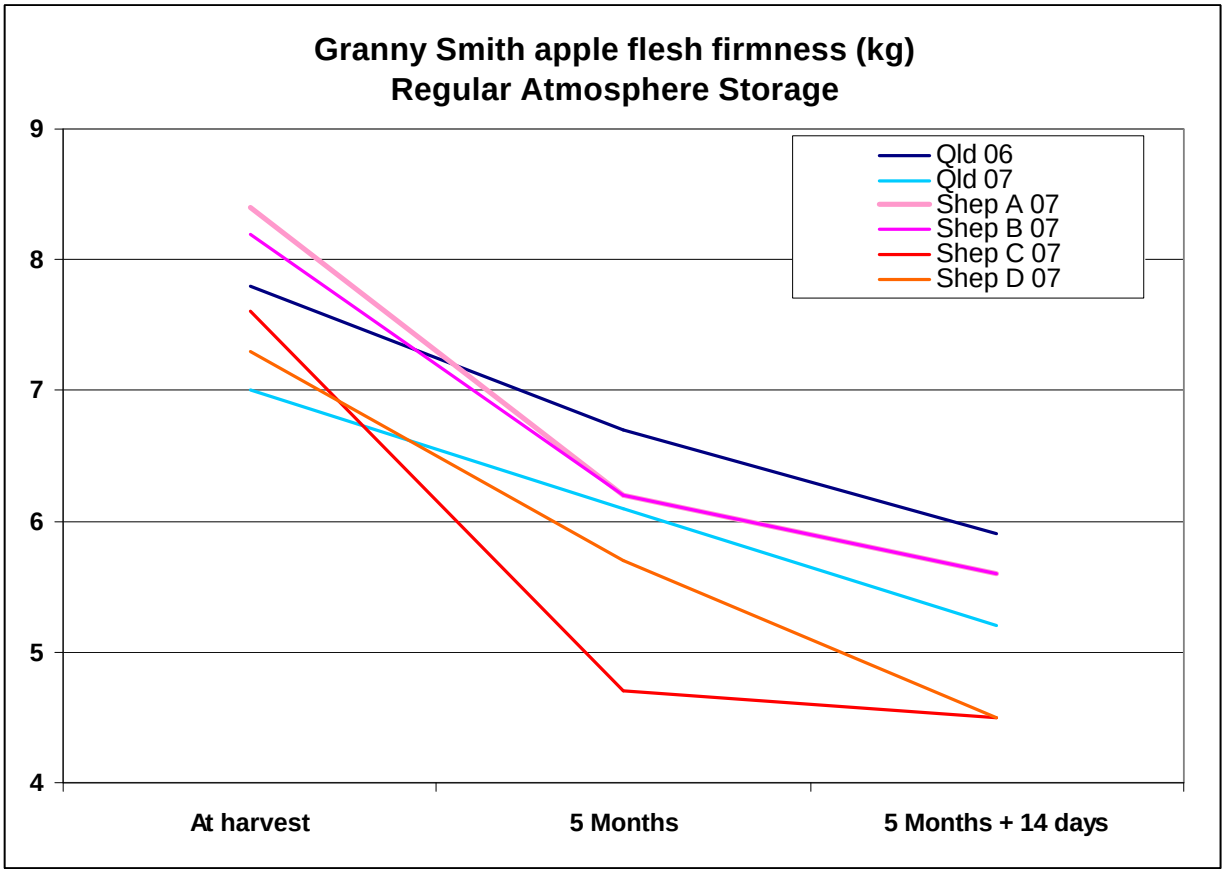
Overleaf are some graphs from trials I have conducted recently with Granny Smith apples from Stanthorpe and Shepparton. They show that;

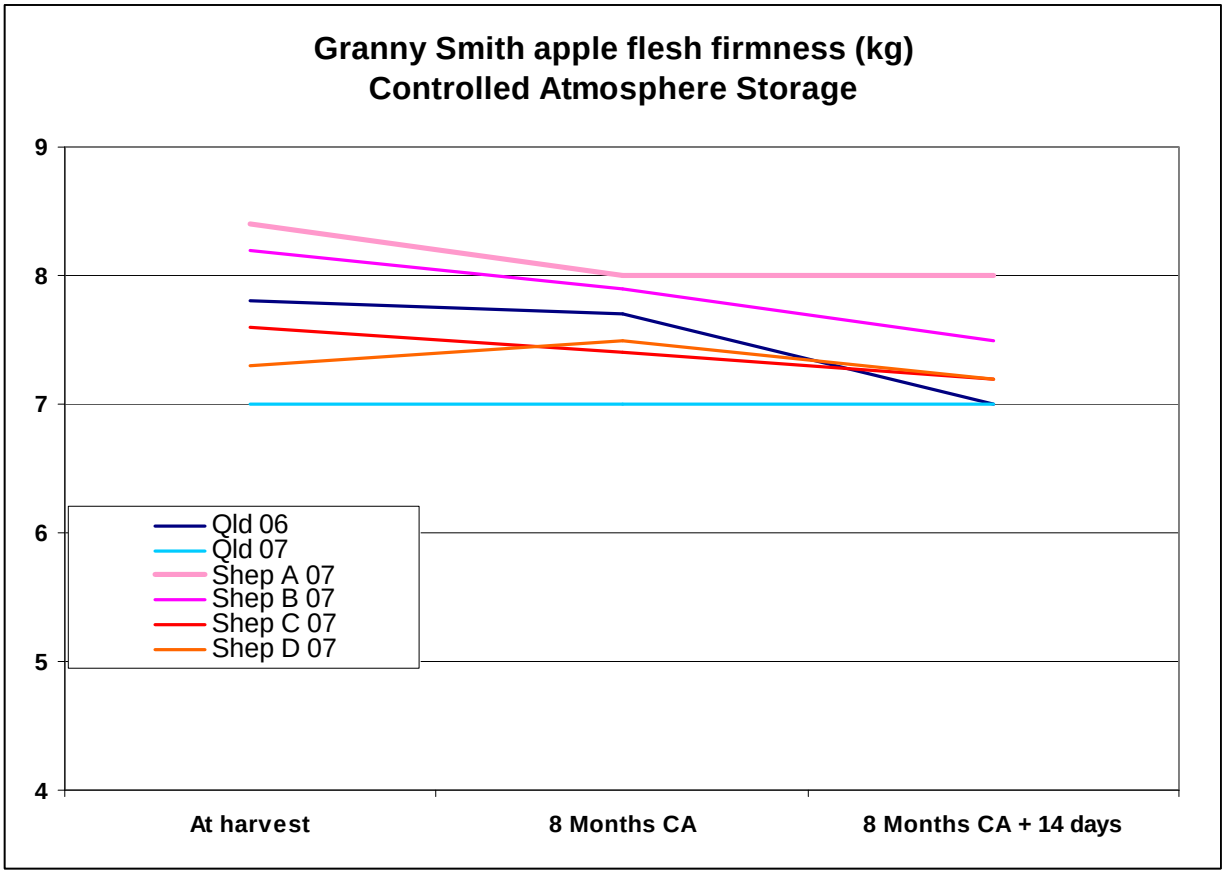
- After 5 months Regular Atmosphere storage the average pressure dropped from 7.7 kg at harvest to 5.9 kg then 5.2 kg after 14 days ambient temperatures on the shelf.

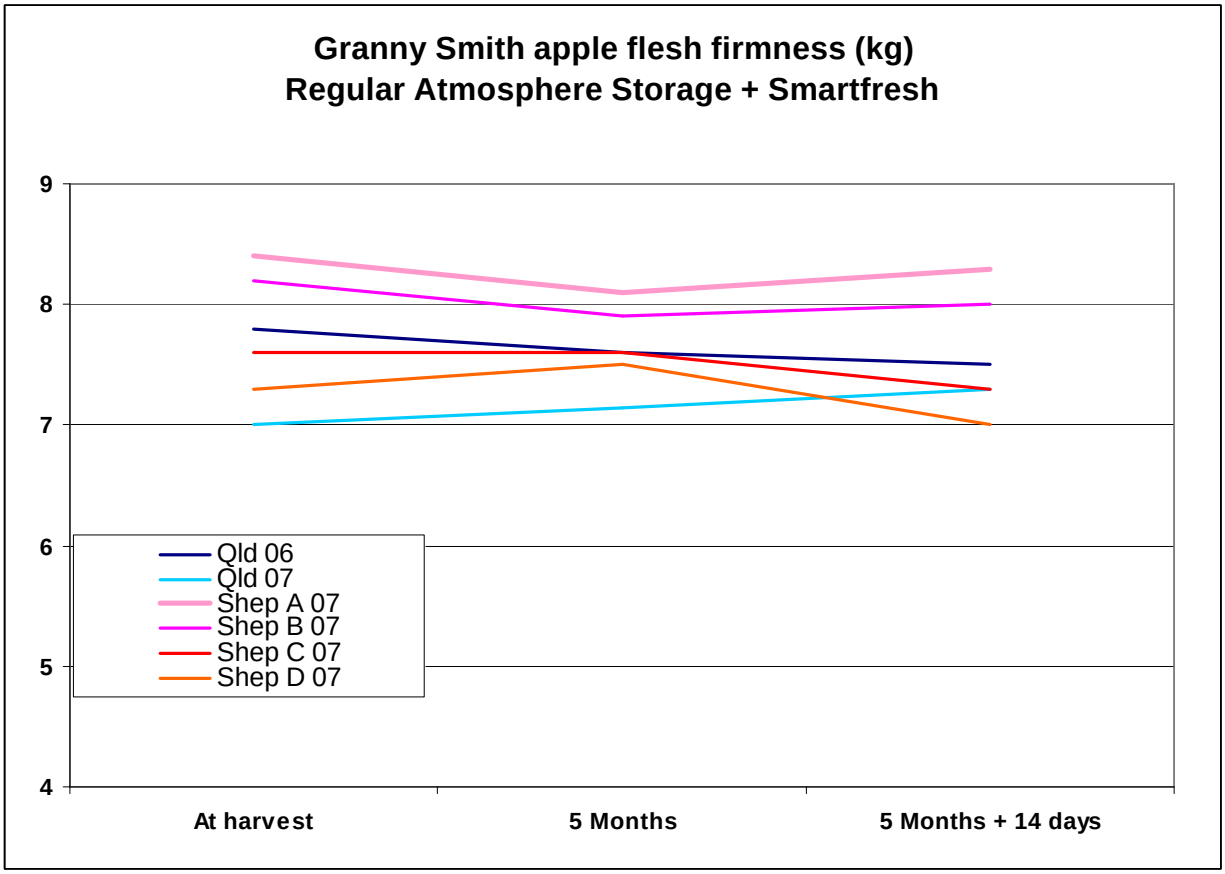
- If Smartfresh was used the pressure after 5 months RA there was no drop in pressure, even after 14 days on the shelf.

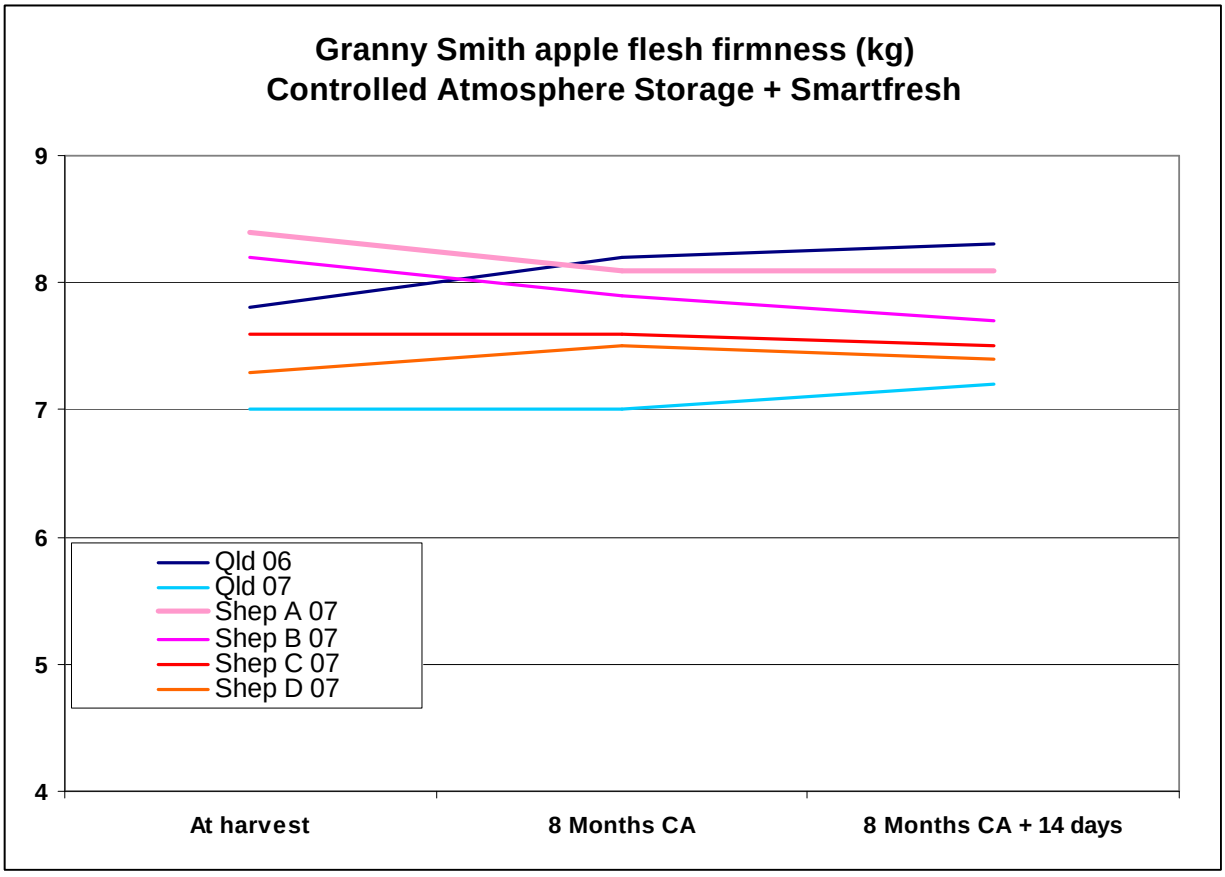
- After 8 months Controlled Atmosphere storage the average pressure dropped from 7.7 kg at harvest to 7.6 kg then 7.3 kg after 14 days on the shelf.

- If Smartfresh was used the pressure after 8 months CA there was no drop in pressure, even after 14 days on the shelf.


Granny Smith apple flesh firmness (kg)
Regular Atmosphere Storage
9
8
7
6
5
4
Qld 06
Qld 07
Shep A 07
Shep B 07
Shep C 07
Shep D 07
At harvest
5 Months
5 Months + 14 days


Granny Smith apple flesh firmness (kg)
Controlled Atmosphere Storage
9
8
7
6
5
4
Qld 06
Qld 07
Shep A 07
Shep B 07
Shep C 07
Shep D 07
At harvest
8 Months CA
8 Months CA + 14 days


Granny Smith apple flesh firmness (kg)
Regular Atmosphere Storage + Smartfresh
9
8
7
6
5
4
Qld 06
Qld 07
Shep A 07
Shep B 07
Shep C 07
Shep D 07
At harvest
5 Months
5 Months + 14 days


Granny Smith apple flesh firmness (kg)
Controlled Atmosphere Storage + Smartfresh
9
8
7
6
5
4
Qld 06
Qld 07
Shep A 07
Shep B 07
Shep C 07
Shep D 07
At harvest
8 Months CA
8 Months CA + 14 days

Measuring sugar

Read about this on pages 129-131 and 145-146 of the green book. Often referred to as TSS or Total Soluble Solids. Close to maturity sugar is the main soluble solid.

TSS is a good indicator of eating quality and flavour, but because it varies so much between season, parts of the tree and districts it is hard to use sugar content as a measure of harvest maturity. But is should be measured and known because it is an important part of the chain store specifications.

TSS is measured by a refractometer and nearly all growers own a hand held refractometer. Electronic refractometers are now becoming less expensive and more common. Electronic devices do not need to be adjusted for temperature, but both devices need to be calibrated with distilled water.

TSS is measured in ^{o}Brix, typically in the range of 9 to 15.

2. 2008 harvest case studies; starch & pressure

The SmartFresh post-harvest treatment system provided by AgroFresh Inc has been a terrific tool developed for storage. Probably the best tool since the development of controlled atmosphere storage (CA). SmartFresh is being used by most growers and I think will eventually settle out at about 70% of all apples being treated. My company is involved as treatment applicators in Stanthorpe and Batlow on a contract basis.

AgroFresh have supported their system with a strong technical program, part of which has involved the collection of harvest maturity data on fruit in rooms they treat in selected districts. They have provided the 2008 harvest maturity data to me for analysis and presentation back to the apple industry so we can continue to promote best practice. No grower names were included with the data, just variety, district, testing date, starch, sugar and pressure.

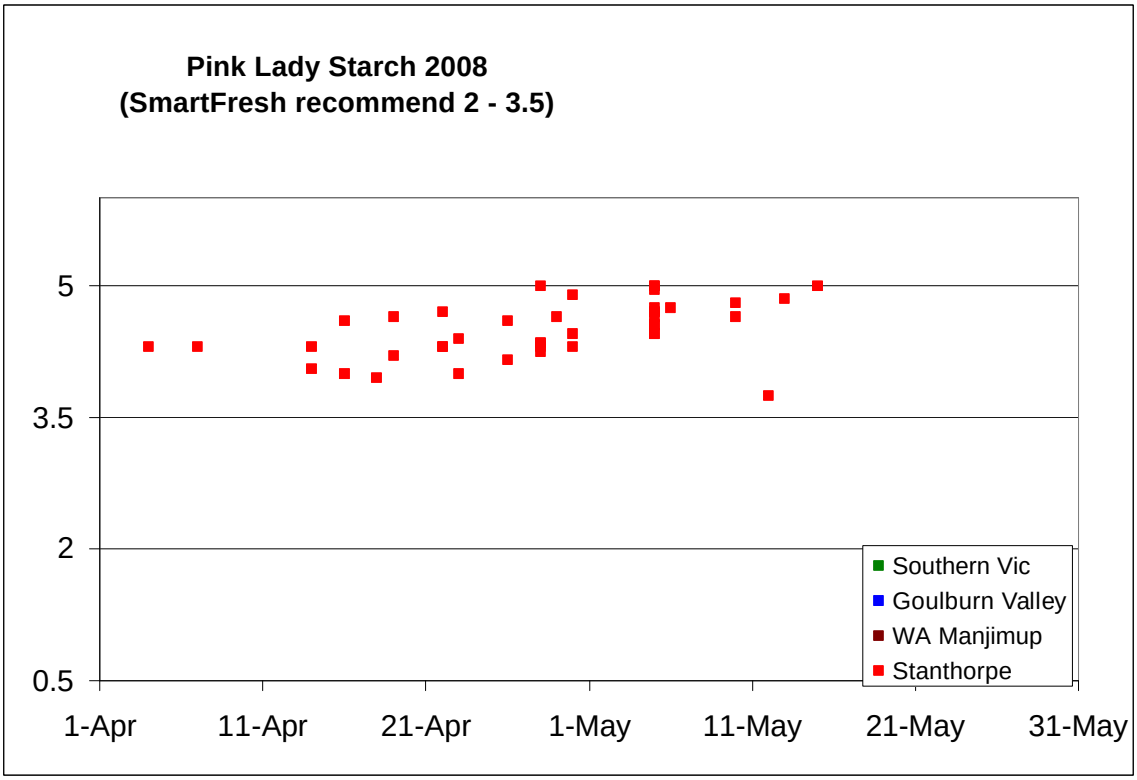
I have distilled out the data for Gala, Granny Smith and Pink Lady and compared it to the guidelines for long-term CA storage. Less than half of the fruit did not meet the starch and firmness guidelines, which is not to say it was poor quality fruit, just that it may have been better quality if it did meet them. Often growers picked fruit with more forward maturity than they would liked to because they have insufficient harvest labour and/or they are waiting for fruit colour to develop further.

Percentage of 2008 harvest samples that had a starch rating suitable for long-term CA storage.

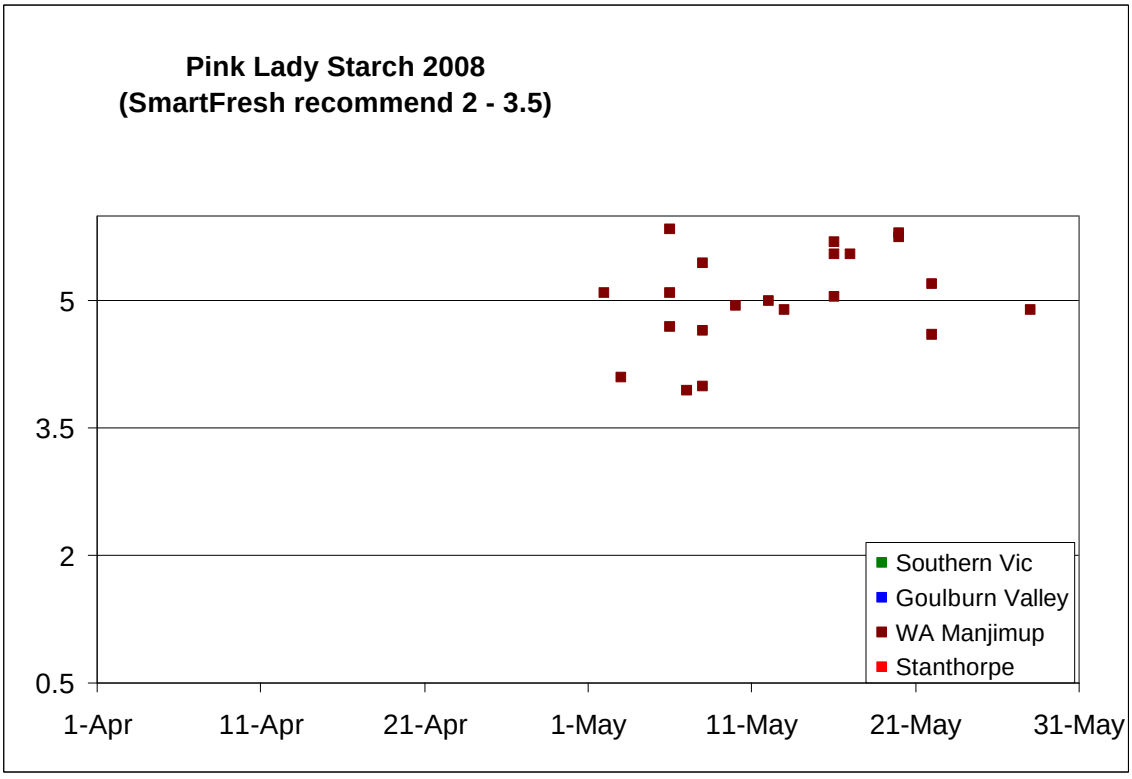
	Southern Vic.	Goulburn Valley	Manjimup WA	Stanthorpe QLD	Average
Gala	37	75	18	42	43
Granny Smith	56	64	4	0	31
Pink Lady	17	13	0	0	8

Percentage of 2008 harvest samples that had a firmness reading suitable for long-term CA storage.

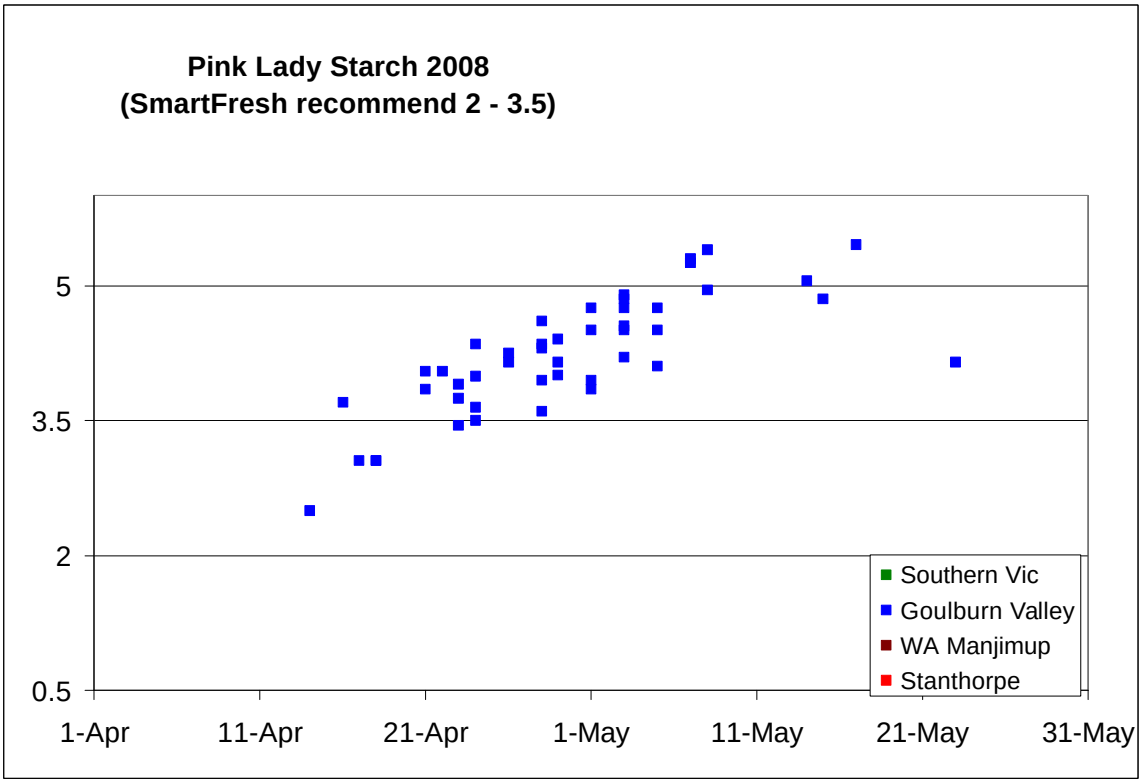
	Southern Vic.	Goulburn Valley	Manjimup WA	Stanthorpe QLD	Average
Gala	85	50	53	23	53
Granny Smith	53	71	0	16	35
Pink Lady	40	22	48	44	39



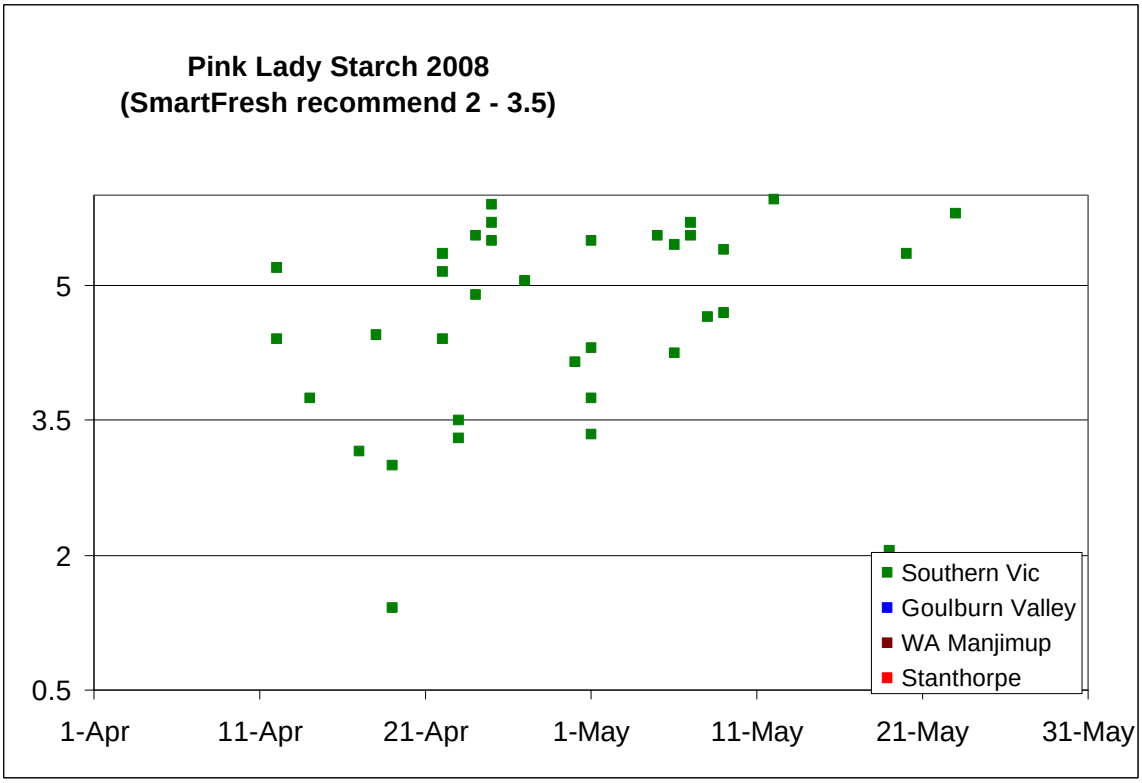
Stanthorpe, Qld.



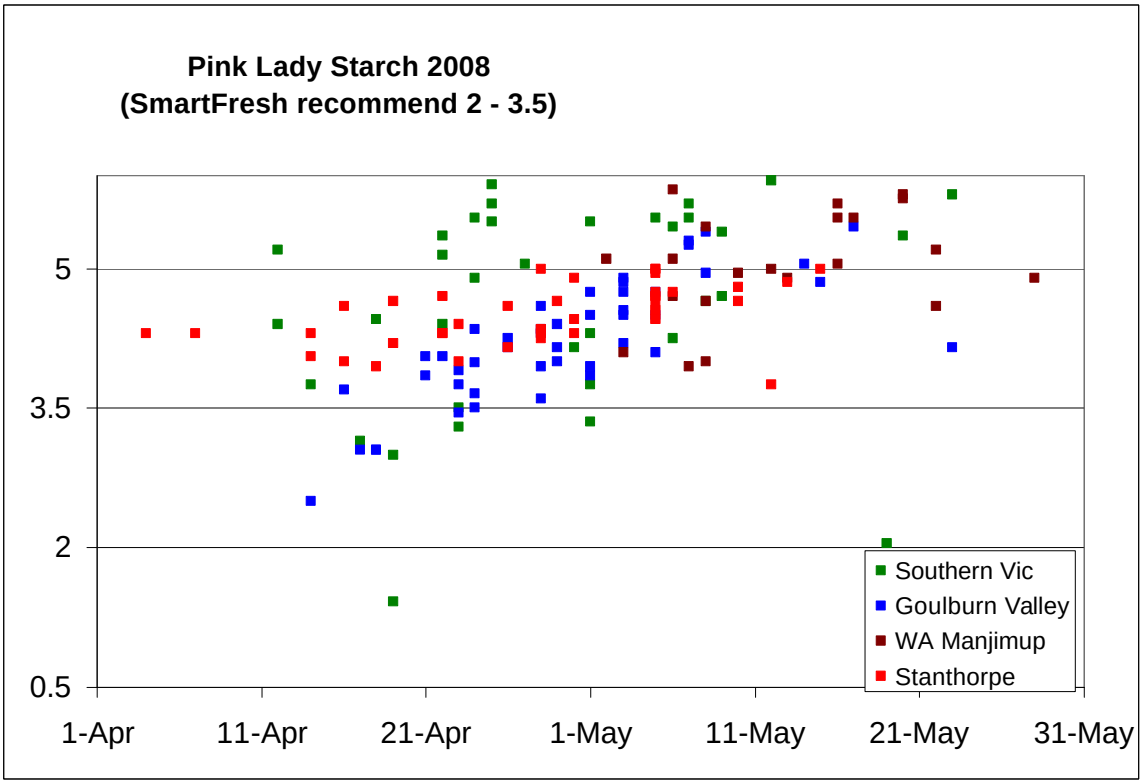
Manjimup WA



Goulburn Valley, Vic



Southern Victoria



Combined Southern Vic, Goulburn Valley, Manjimup and Stanthorpe

3. Pink Lady flesh browning

Internal or flesh browning is a major disorder of the Pink Lady variety and is topical at present because some growers had major losses because of this in the 2007-08 season.

There are 3 types; diffuse, radial and cavity. Cavity type browning is a CO_2 issue and is a problem in all varieties, not just Pink Lady, so I'll not discuss it here.

Diffuse browning is more common in cooler climates and is mainly a chilling injury disorder. Radial flesh browning is more common in warmer climates and is mainly a senescent breakdown disorder.

A lot of good work has been done by a team of researchers working in Australia, New Zealand, Italy and USA and an excellent summary of the latest findings was published in 2008 by Dr Jenny Jobling of Applied Horticultural Research and Horticulture Australia Limited (HAL) in 2008. *Managing the flesh browning disorder of Cripps Pink apples.* This booklet was distributed to apple growers with the Australian Fruitgrower magazine in early 2008 and a copy is available on the APAL website.

Risk Factors and Causes:

- The first point to remember that this disorder is not caused by a single factor. There is no 'silver bullet' to prevent this disorder.

- The longer fruit is kept the higher the risk of flesh browning occurring. There is more risk with fruit kept after September.

- Advanced maturity is very important and more important in the warmer climates. But you can get flesh browning with early picked fruit if the other factors are wrong.

- Second pick fruit is higher risk than first pick fruit.

- High CO_2 (anything above 1%). Note that regular atmosphere (RA) has very low CO_2 (0.05%) and flesh browning is not usually a problem in RA. With Pink Lady damage can initiate early in storage, that is while the room is being filled and before CA has been imposed. Opening the door and venting the room air during filling and pull down and adding hydrated lime early can reduce the early CO_2 build up.

- Low O_2 (1.5% and below) is a factor.

- Smartfresh has neither a positive or negative affect on flesh browning. However, if Smartfresh is used the destructive affects of ethylene are negated. This will help maintain fruit quality when step wise cooling, storing at elevated temperatures and delaying the introduction of CA conditions are employed.

- Dipping fruit in DPA reduces the risk of flesh browning.

- Delaying the imposition of CA conditions reduces the risk of flesh browning

- High calcium reduces risk (but low calcium doesn't cause it).

- High crop loads can increase susceptibility. Probably related to fruit being stressed and possibly harvested later.

- Step-wise cooling will reduce the risk. If you harvest fruit late and don't use Smartfresh you may not have the option of step-wise cooling as fruit may go forward quickly as ethylene production may be advanced.

- Storing fruit warmer than 0°C reduces the risk. Up to 3°C if fruit is grown in a cool climate and diffuse browning (a type of chilling injury) is the main concern. Up to 1°C if fruit is grown in a warmer climate and radial browning (senescent breakdown) is the main concern. Storage at up to 3°C may reduce the other quality characteristics of fruit eg loss of firmness, development of rots. Loss of firmness will be mitigated if Smartfresh is used.

- Cool growing seasons increase the risk of flesh browning. This is particularly important in the naturally cooler districts. A climate model has been developed by Jenny Jobling and her team using Growing Degree Days (GDD).

All these factors can be adjusted & managed to some degree except the last one (climate). However it should be measured so that the relative risk can be assessed each year. One way of measuring cool growing seasons is to measure Growing Degree Days (GDD).

The daily GDD are calculated by; [(max. temperature + min. temperature) / 2] – 10

To get the seasonal GDD you sum all the daily GDD's. I have calculated these for some selected districts. Note that I used 1st October as a common full bloom date and 21st April as a common harvest date. These won't be correct for all districts or all years but will allow us to look at some general differences and trends.

	Long term average GDD	2007-08 GDD	2007-08 comment
Shepparton	1921	2042	6% Warmer
Stanthorpe	1720	1591	7% Cooler
Manjimup	1607	1655	3% Warmer
Sth Australia #	1568	1612	3% Warmer
Orange	1392	1302	6 % Cooler
Sth Victoria*	1386	1540	11% Warmer
Launceston ^	1113	1148	3% Warmer

Data from Mt Crawford, * Data from Coldstream
^ Data from Launceston airport. Only 4 years available and many gaps exist.

Jenny Jobling has provided a comment to help interpret some of the district GDD data "The cut offs are based on the districts we had in the trials. So 1700 GDD was California and they never saw flesh browning. 1100 is the cross over point for Radial and Diffuse flesh browning. The Yarra Valley often has GDD of 1100 to 1200 GDD and they see both types of symptoms. The Huon Valley which is about 900 GDD gets Diffuse FB and the Batlow at about 1400 gets Radial flesh browning so we don't have data for all GDD values in between.

But as a guide we have said;

- above 1700 risk is very low
- between 1400 to 1600 you are prone to Radial Flesh browning
- between 1400 to 1100 you might see both types of symptoms
- and below 1100 you will only see Diffuse browning.

And within a range the lower the GDD the great the incidence of that type of FB."

The apple industry was fortunate to have had Hannah James complete a PhD study at The University of Sydney in 2007 titled *Understanding the flesh browning disorder of 'Cripps Pink' apples*. She has produced two charts that help assess the risk of the two types of flesh browning. They are reproduced below with kind permission of Hannah who is presently working in a post doctoral position at Cornell University's New York State Agricultural Experiment Station.

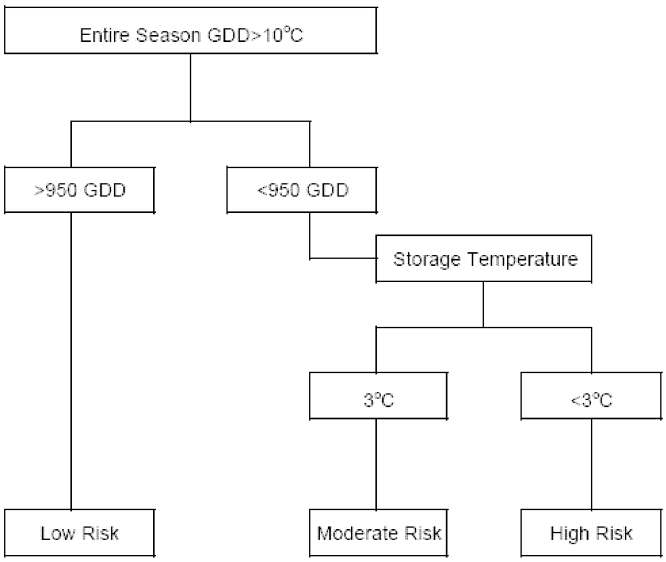


Figure 6.2 Risk factors for the development of diffuse flesh browning (DFB) of 'Cripps Pink' apples during storage.

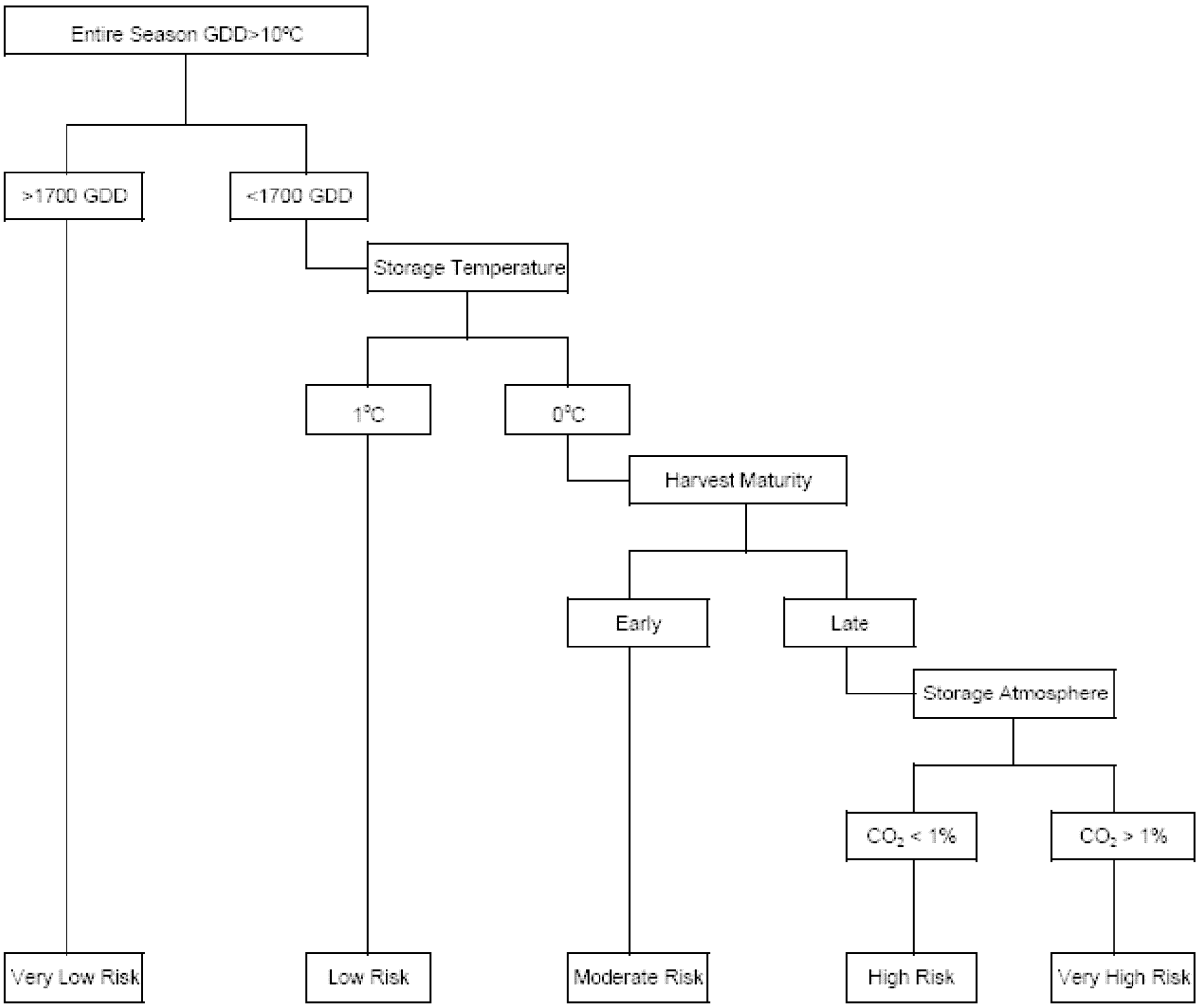


Figure 6.3 Risk factors for the development of radial flesh browning (RFB) of 'Cripps Pink' apples during storage.

What has the season been like in your district this year?

	Long term average GDD to 14th Jan.	2007-08 GDD to 14th Jan.	2008-09 GDD to 14th Jan.
Shepparton	892	1066	834
Stanthorpe	840	858	874
Manjimup	704	701	655
Sth Australia	735	827	605
Orange	643	702	577
Sth Victoria	634	795	561
Launceston	490	549	365

The 2008-09 season so far in Southern Victoria, Orange and South Australia is looking to be cooler than usual. However, this data must be interpreted with caution as only 51% of the growing season for Pink Lady has occurred by 14th January. GDD models should be checked again in March and April.

4. Lets talk about colour

Red skin colour is a major motivator for fruit wholesalers and retailers, and allegedly consumers. That's not such a bad thing as well coloured fruit can cover up small superficial picking bruises and overshadow russetted or prominent lenticels and is easy for pickers to recognise. I suppose the objection comes when colour is used exclusively and all other quality issues are ignored or downplayed – until something goes wrong, like fruit softening or cutting brown.

How can a grower improve colour? Well the nurserymen and plant breeders have played their role and supplied red strains of all our popular varieties, but often the red colour comes a bit late to coincide with other optimum quality parameters or it's too slow to develop throughout the whole tree canopy.

I'm always asked; *how can I improve fruit colour*?

There are some obvious answers;

- Plant red strains.
- Use a dwarfing rootstock so there is not excessive growth and shading.
- Grow your tree as a central leader to maximise light interception.
- Avoid setting light crops as the tree may grow shading shoots instead of fruit.

- BUT by the time the question is asked it's probably too late for these remedies.

There are some things that you do within a season;

- Don't let potassium deficiency develop. Even on soils naturally high in potassium you should be aware that 80 to 100 kg per hectare of this element is walking out of the paddock each year. As trees get older this adds up to several tonnes, and is coming out of the same areas of soil around the feeder roots. And for interest, I don't recommend foliar potassium be used unless you are in real trouble. It is usually just potassium deficient trees that respond to foliar sprays.

It is impossible to supply the full program in a foliar form and you run the risk of interfering with calcium nutrition.

- Water well. Stressed trees can have well coloured fruit (on the outside of the canopy) but it is also smaller and yield suffers. Only unstressed trees can grow big crops and mature and colour them well. Optimum watering and regular rainfall can counteract colour development by promoting shoot growth and shading fruit. So the accelerator of good soil moisture needs to be geared down by rootstock, pruning, Regalis and crop load.

- Summer prune. Improves light penetration but labour is expensive and well trained labour very hard to find (and keep).

- Use reflective mulches (eg Extenday) to get light to the shaded parts of the canopy and onto the downward facing parts of the fruit. Very effective but comes at a cost. However if used early enough it can increase yields significantly and pay for itself very quickly.

- Use Regalis as a brake to vigour. This product is in its 3rd commercial year in Australia now and is a standard treatment in some orchards where it has resurrected bad blocks, improved fruit set, fruit size and fruit colour in a lot of blocks and generally improved packouts. However it comes at a financial cost and is seen as an artificial remedy to 'good agronomy' by some orchardists and advisors. When you use Regalis you change the dynamics of the tree and some readjustment in thinning, watering/fertilising and pruning is needed to maximise the benefits.

  We have had a lighter crop set in Queensland this year and a lot of rain in November and December, and you can split the orchards into three types;

  - those that didn't need Regalis because they had everything in balance.

  - those that needed Regalis and received it.

  - those that needed Regalis and didn't receive it. These are the blocks where you can't see much fruit because of the shoot growth. And naturally if the fruit is hard for us to see then it is hard for the sun to reach it and colour it.

- Use Retain to slow down ethylene production and ripening and if the weather is right you can increase the overall level of fruit colour.

There are some things you could do late in the season, but are NOT recommended;

- Leaf plucking, or removal of the leaves immediately adjacent to the fruit. It does improve fruit colour but should be considered a last resort. It is expensive and it also deprives the fruit of the sugar/starch factory that is needed to finish off the fruit flavours and maturity.

If none of the above have been tried or they all didn't work then the only thing you can do to improve colour is;

- Leave the fruit on the tree another 14 days. It usually colours up well but marketing options are then limited to fresh market or very short-term storage because the starch has disappeared, the firmness has dropped and the ability to hold firmness after storage has disappeared.

5. Scald control options

Superficial scald is a physiological disorder of the apple skin.

Scald is more prevalent;

- in early harvested fruit
- in regular atmosphere storage
- in susceptible varieties (especially Granny Smith and Red Delicious)
- in hot, dry seasons and districts
- in high nitrogen and low calcium nutritional situations

The main control option for many years has been treating fruit with the antioxidant diphenylamine (DPA). It is very effective, but is not the cleanest-greenest product to be applying to our fruit and indeed many overseas countries have prohibited DPA use for many years.

Used DPA dips are not easy to dispose of and there are operator concerns within packing sheds. Industry has long looked for alternatives to DPA and the development of ultra-low CA was partly because fruit stored in low oxygen (~1.5 to 1.8%) was less prone to scald and DPA use could be reduced or eliminated.

However the registration of SmartFresh for "preventing superficial scald on apples" growers now have real options.

To control scald SmartFresh must be applied within 7 days of harvest, and I think 5 days is a better option for the earliest picked fruit (especially GS). I saw the potential for DPA reduction when SmartFresh was first introduced to the Australian industry but like many was cautious. I conducted trials on Granny Smith in Stanthorpe in 2006 and 2007 and on four lines of fruit in Shepparton in 2007. The results were outstanding and I'll share some of these with you today.

The trial fruit selected from the first picked commercial lines so it was very prone to scald. It received DPA treatment in a grower's standard dip and was treated with SmartFresh as part of a commercial room treatment. Fruit was store in commercial regular atmosphere or controlled atmosphere rooms. One hundred fruit, of a common size, with no visible sunburn damage were used for each treatment.

The consistent results were;

- SmartFresh treated fruit had the less superficial scald than DPA treated fruit.
- There was no advantage of combining DPA and SmartFresh treatments.
- In some cases (albeit extreme conditions) DPA failed to give a commercially acceptable result.
- CA stored fruit had less scald than Regular Atmosphere stored fruit.
- Scald took longer to develop in CA conditions than in Regular Atmosphere conditions.

Stanthorpe Granny Smith superficial scald trial results, 14 days after room opening.

Storage*	Smart Fresh	DPA	% Scald			
			2006		2007	
			4 months	8 months	4 months	8 months
RA storage	×	×	94	-	100	-
	×	✓	9	-	31	-
	✓	×	0	-	0	-
	✓	✓	0	-	0	-
CA storage	×	×	0	76	-	100
	×	✓	0	8	-	93
	✓	×	0	0	-	1.3
	✓	✓	0	0	-	0

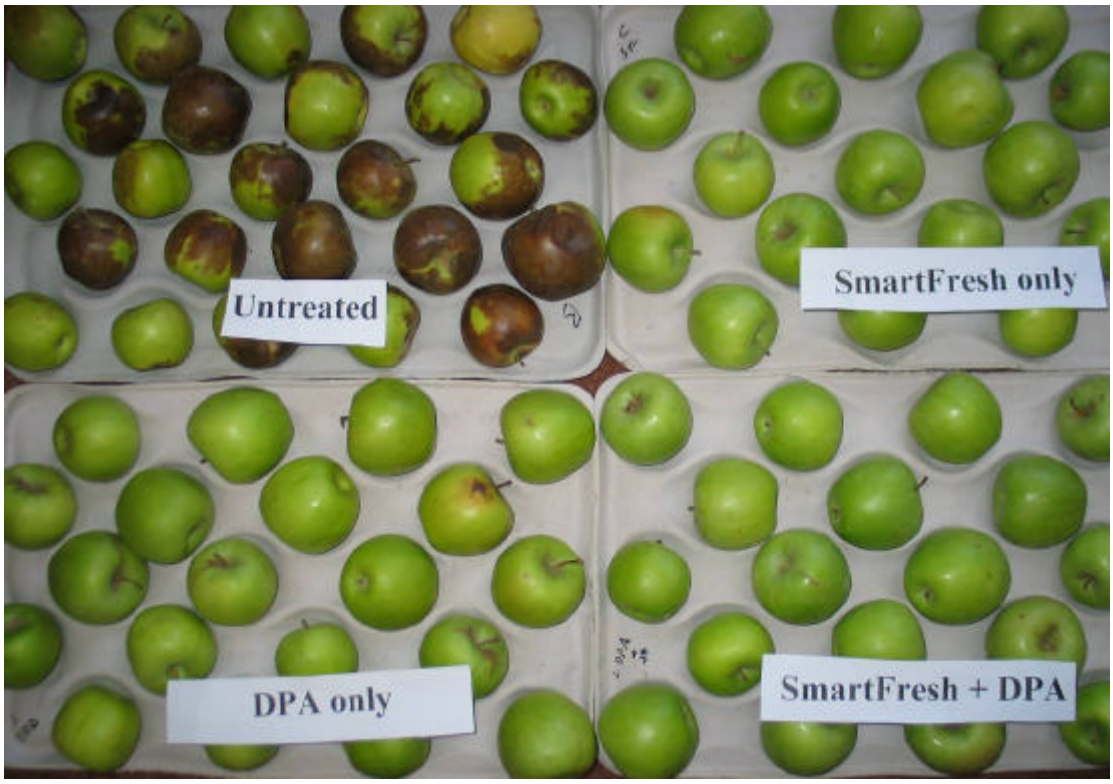
* RA - Regular Atmosphere, CA – Controlled Atmosphere

Shepparton Granny Smith superficial scald trial result, 14 days after room opening.

Storage*	Smart Fresh	DPA	% Scald			
			2007			
			Grower A	Grower B	Grower C	Grower D
RA storage 5 months	×	×	100	100	100	100
	×	✓	57	29	0	17.3
	✓	×	0	0	1.4	0
	✓	✓	0	0	0	0
CA storage 9 months	×	×	12	1	2	5
	×	✓	2	2	2	0
	✓	×	2	0	0	0
	✓	✓	1	0	0	0

* RA - Regular Atmosphere, CA – Controlled Atmosphere

Stanthorpe Granny Smiths after 8 months CA storage, 2007.



Shepparton Granny Smiths after 5 months RA storage, 2007.