SUGGESTIONS FOR MINIMISING SOFTENING AND FLESH BROWNING IN PINK LADY APPLES FOR 2003.

Compiled by Colin R. Little

The following ten points are given in order of importance with [1] as most important on to [10] as of least importance but which is still a factor that must be incorporated in a formulating a Pink Lady storage program.

[1]. MATURITY

The simplest test for maturity measurement in the field and to give results on the spot is the starch test. Procedural details are given in the attached report:- 'Factors that affect the storage and marketability of Pink Lady apples'.
To use the starch test for measuring maturity a 'Maturity Manual' showing the 9 levels of staining from fully immature to fully ripe is needed. This set of colour plates shows immaturity (too unripe to pick for storage) as PLATE 1 (full stain, black) through in stages of diminishing stain to PLATE 9 (no stain- white). In this series PLATE 2 to 4 (approximately 80 % to 50 % stain) is considered OK for long term CA storage. This maturity range is classified as suitable for long term CA storage. This maturity range is classified as 'suitable for long term CA storage (LTCA). Category LTCA. I is starch PLATE 2 or 70 % to 80 % stain. Category LTCA.2 is starch stain PLATE 4 or 50 stain. LTCA.2 is recognised as being the maturity stage at which Pink Lady are at the point of becoming unreliable for storage in (ULO) CA which is extended past midOctober. Maturity category Medium Term CA I (MTCA.1) shows a starch stain of 40 to 50 % or PLATE 5 and MTCA.2 shows a starch stain of 30 %, PLATE 6. Maturity category short Term CA 1 (STCA. 1)shows a starch stain of 10 % (PLATE 8). when Pink Lady are fully tree ripe there is 5 % stain or less as is shown in PLATE 9.
Maturity is a complex thing and all fruit on a tree do not have the same maturity status on the same day. It is a physiological fact that first out flowers mature first. Generally Pink Lady mature first from the bottom of the tree and last from the top. Colouring, however, is in the reverse order with top fruit colouring first and bottom fruit last.

STORAGE LIFE MUST BE LINKED TO THE MATURITY ASSESSMENT AT HARVEST. THE MATURITY ASSESSMENT IS MADE ON FRUIT FROM THE MID OUTER CANOPY OF THE TREE.

GENERALLY WITH PINK LADY A TOP 'COLOUR PICK' IS MADE FIRST. THIS COLOUR PICK IS USUALLY CATEGORISED AS LTCA MATURITY CLASS, BUT IS OFTEN MARKETED AS THE FIRST ONTO THE MARKET 'COLOUR PICK'. THIS FRUIT IS SUITABLE FOR LTCA STORAGE TO EARLY/ MID OCTOBER.

THE NEXT PICK IS MADE SEVERAL DAYS LATER. IT IS OF THE UTMOST IMPORTANCE TO KNOW WHETHER THIS SECOND PICK IS AT (LTCA) OR (MTCA) MATURITY CATEGORY. IF AT (MTCA) CATEGORY DO NOT STORE IN (ULO) CA AFTER MID TO LATE AUGUST. THE FINAL STRIP PICK FROM

THE INNER LOWER PART OF THE TREE IS MADE LAST BECAUSE THERE IS ALWAYS A LONG WAIT FOR THIS FRUIT TO COLOUR.
THIS 'LAST OFF THE TREE' PICK MUST BE ALLOCATED TO SHORT TERM CA (STCA.2) AND HARDLY EVER KEEPS IN A SATISFACTORY CONDITION EVEN IN (ULO) CA AFTER EARLY JULY. THE RULE MUST BE FIRST OFF THE TREE IS FOR LONG TERM STORAGE. LAST OFF THE TREE IS FOR SHORT TERM STORAGE. FRUIT OF EACH MATURITY CATEGORY MUST BE SCHEDULED FOR THE APPROPRIATE STORAGE PERIOD.

Where Pink Lady reach an LTCA maturity category but show inadequate red colour for specific market requirements deliberately delaying picking to STCA maturity category while waiting for increased red colour must be followed by a storage period which is appropriate to the STCA maturity category. MARKET THESE BEFORE MID-JULY AND CERTAINLY NOT ON TO MID-OCTOBER. OVER MATURITY INCREASES SOFTNESS, DRY TEXTURE, GREASINESS AND FLESH BROWNING

[2]. MAINTENANCE OF LOW CARBON DIOXIDE.
Pink Lady apples are very intolerant of carbon dioxide in CA storage. The degree of intolerance increases with an increasing maturity status at harvest, and to stress conditions in CA storage caused by very low oxygen levels and very low temperature at the start of storage.
An ideal carbon dioxide is 0.5 % to 1.0 %. This is difficult to achieve in commercial CA storage operations while still holding oxygen to 1.8 % to 2.2 % which is an ideal level. It may therefore pay to trial some CA rooms using 8 to 10 kg. of Lime/ bin of stored fruit. This should hold carbon dioxide at 1.0 % during the initial months of storage. The use of bi-regimen (or two stage) CA may be worth a try. This is where carbon dioxide is held lowest (< 1.0 %) and oxygen lowest (1.8 %) with 'step-wise' initial cooling (4°C for the first 10 days after sealing the room to 2°C for the next 20 days then to 1 °C to 100 days). After the hundredth day carbon dioxide can drift up to 1.5 % and oxygen to 2.5 % while temperature is reduced to 0°C.

[3]. THE CHOICE OF STORAGE CONDITIONS.
It is true that in standard cold storage at 0°C to I 'C flesh browning (FB) is rarely a problem. The trouble is that with standard cold storage, there is a more rapid loss if firmness, texture, and acidity and the apples tend to go yellow and greasy. NOTE : - The degree of softness, textural loss and greasiness will increase as the maturity of the Pink Lady received into cold storage is progressively more ripe. In simple terms, standard cold storage is used to hold the last picks for no more than six weeks. Cold storage is also used as a very short term holding facility while marketing the contents of a CA room.
Standard commercial CA, {(STD) CA} is the most commonly used CA in Australia but not in other countries. This type of CA is used because :
(a) rooms are not gas tight and it is not possible to hold oxygen at 1.8 % to 2.2 %. (b) it is too difficult to hold carbon dioxide at the lower levels needed with very low oxygen. (c) there is a feeling that very low oxygen CA is too risky. (d) there is an attitude of miss-

trust in the claims that very low oxygen will deliver longer life in CA. Standard commercial CA is where rooms are filled in 7 to 14 days, oxygen pull down starts soon after sealing the room and carbon dioxide is held around 2.5 % to 3.5 %. Room air temperature is 0°C to I 'C. Under these conditions Pink Lady apples become unacceptably soft and begin to show FB symptoms if the (STD) CA is extended beyond mid August, mid July and early June where harvesting was at maturity category LTCA, MTCA and STCA respectively.
Ultra low oxygen CA, {(ULO) CA }. Running a successful (ULO) CA facility requires a carefully monitored program. This can be made more user friendly with an automated CA system using a Nitrogen generator and a specifically designed scrubber that does not ingress oxygen in the carbon dioxide scrub mode during de-sorption. The system won't work if room leakage exceeds an ingress rate of > 0.2 % of oxygen per day. The schedule for (ULO) CA is to fill the room in 7 days, seal on day 8 and start oxygen reduction. Reduce oxygen to 5.0 % by day 9 from fruit intake and to 1.8 % by day 14 to 15 after first intake.
Oxygen set point is 2.0 %. Range is from 1.8 % to 2.2 %. Carbon dioxide set point is 1.0%, and range is 0.8 % to 1.0 %. For temperature, use step-wise cooling ; 4°C while loading and to day 10 after room sealing, then change to 2°C for 20 more days then change to I 'C to day 100. With (ULO) CA Pink Lady maturity categories LTCA, MTCA, and STCA can be stored with minimal loss of firmness and onset of FB until early November, early October and early August respectively. While (ULO) CA assists in extending storage life, it is wrong to assume that it will provide long term storage regardless of the maturity status at harvest. Maturity status and the maintenance of carbon dioxide at < 1.0 % is the key to successful (ULO) CA storage with minimal FB, and even with the best storage facility it is a mistake to assume that technology will allow over mature Pink Lady to store long term.

[4]. AVOIDANCE OF STRESSFULLY LOW OXYGEN LEVELS.
The capacity of carbon dioxide to cause FB increases substantially if oxygen levels fall below *1.5%.*
Under these very low oxygen conditions, the damage that causes FB is initiated early in storage
but does not show as browning until later in storage. The severity of FB caused by low carbon dioxide is greater where there is a combination of low oxygen and low temperature stress.

[5]. AVOIDANCE OF OVER EXTENDED STORAGE PERIOD.
There are many 'secondary' conditions that tend to reduce storage life (based on loss of firmness and onset of FB). Therefore there are some seasons when Pink Lady at maturity categories LTCA.1 to LTCA.2 store in (ULO) CA with minimal loss of firmness or onset of FB through to mid-November or later. In other seasons apples of similar maturity stored in the same storage conditions show excessive softening and FB by early October.

[6]. TREE NUTRITION.

In the case of Pink Lady apples mineral levels in fruitlets and fruit at harvest (maturity category LTCA. 1) give a much more reliable indication of the nutrient status of the tree than a leaf test in late January. The main thing with Pink Lady is that the nitrogen level in fruit must be 20 % lower than for Granny Smith. Luxury levels of nitrogen are appropriate for Granny Smith to maximise apple greenness and to shade fruit from sunburn rather than to promote yield per hectare.

Pink Lady become very reluctant to colour when the benchmark value for nitrogen is exceeded.

High nitrogen levels in apples increase the respiration rate (rate of living), the cell size but not the cell number and makes it more difficult to increase calcium and phosphorous levels in apples.

With regard to softening, nitrogen tends to soften while calcium and phosphorous tends to harden apples. Zinc tends to promote earlier tree activity at the break of dormancy and this increases transpiration and the transport of calcium and phosphorous reserves in the roots and wood to the fruiting points at flowering time.

With regard to sugar levels, potassium is the element that is most likely to improve apple sweetness, but then only if manganese and magnesium are at benchmark levels. With regard to reducing FB, increased phosphorous levels are probably more useful than increased calcium. However, increased calcium gives more stable cell wall structure and it is believed that cell wall leakage is the trigger mechanism that leads to the development of FB. It is also important to make sure that potassium and boron do not ride at a consistently higher level than calcium, phosphorous and magnesium. Volumes have been written on the subject of apple tree nutrition. Therefore this briefest of statements on tree nutrition is given as a reminder that nutrition does have a significant influence on apple quality and storability. As a simple guide, aim to achieve benchmark values for mineral levels in Pink Lady apples. These are Nitrogen 0.191 %. Phosphorous 0.071 %, Potassium 0.67 %, Calcium 0.036 %, Magnesium 0.033 %, Zinc 12 ppm, Copper 8 ppm, and Boron 21 ppm. For further information contact the author OR the Phosyn website (http://www.phosyn.com).

[7] SEASONAL EFFECTS.

There is not much detailed information available at this stage to identify the nature of seasonal conditions that cause reduced storability. The information available shows that cool wet and drizzly Spring weather followed by mild and cloudy coastal summer weather leads to a reduction in storability. These conditions are more likely in Southern Victorian districts, high country locations and from some locations in Tasmania or the south west of Western Australia. It is also known that Pink Lady are less reliable in storage if they are sourced from some high country locations, and from the cooler locations of Southern Victoria and Tasmania, and are more reliable in storage when sourced from Northern Victoria or Western Australia.

The question as to why these seasonal effects lead to increased FB and an earlier onset of the disorder in storage are being researched internationally over the coming two seasons. The most favoured theory is that wet , cool, dull, and drizzly Spring weather significantly delays tree growth activity in the critical stage from bud burst to fruitlet formation. Transpirational activity in the tree is responsible for the movement of hormones and

nutrients from the root zone to the vegetatively growth zone. Maximisation of this activity is dependent on a vigorous uninterrupted rate of transpiration. Uninterrupted Spring sunshine following the break of dormancy, such as occurs in the Columbia River Valley in Washington and British Columbia stimulates transpiration, minimises the time span from blossom burst to petal fall and guarantees a high cell number count in apples during cell division which takes place in a brief 60 day period from full bloom. Stop-start Spring weather (miserable, dull, drizzly, windy conditions interspersed with the odd day of calm warm and sunny conditions) minimise the chance of maximising cell number. In addition, calcium uptake is retarded, the uptake of nitrogen as the most mobile nutrients uninhibited, phosphorous levels remain static and zinc which assists transpiration is locked up in growth and fruit buds and in roots. The end result is that the blossom period extends over a 14 to 20 day span rather than a 10 day span, cell numbers are low, bee activity is minimal (bees stay home at < 15 °C with wind velocity to > 20 km. / hr.), seed count is low and maximum tree biomass (total leaf volume at the end of the initial vegetative growth phase) is late.

These conditions give low cell number, poor cell wall structure (low calcium and phosphorous) wide variability in maturity within the fruit population on the tree, poor seed count (seeds produce hormones which during cell division assist in maximising cell function and are also responsible for uniform shape and skin texture) and a higher risk of fungal disease.
In these inclement Springs, the days that are suitable for spraying are limited and on the good days priority is given to the control of fungal diseases. Leaf and fruit cuticle and tissue structure is soft and excessive chemical application over a contracted period can cause russet. Application of foliar nutrients therefore tends to be delayed or omitted.
It is almost inevitable that calcium and phosphorous levels in the fruit following on from a lousy Spring are low. They were lower than benchmark values in 2001/2002. After poor cell division (low cell count) Pink Lady make size by maximising cell expansion. This takes place from mid-December on to harvest.
Hill country Pink Lady tend to be more variable in the rate of maturation and can lack cell numbers. In these locations maturation and cell count is influenced by the altitude and by landscape conformation. Problem spots are in shaded valleys which are denied afternoon sun as the sun angle lowers through March and April.

[8]. ORCHARD LOCATION WITHIN AUSTRALIA.

Problem areas are the cooler coastal and mountain locations. Maturity assessment in these areas should be more detailed with particular attention being given to the degree of variability noted at each maturity assessment. Variability is higher in these 'at risk' locations.
Fortunately colour expression and intensity is usually earlier but careful attention to rapid change in maturity status us critical.

[9]. ROOTSTOCK EFFECT.

Since sunlight interception is a prime requirement for Pink Lady colour, low tree biomass is more favoured than high tree biomass. This does not say that trees on vigorous stocks will not produce good Pink Lady. It does show that trees on low vigoured stocks will produce a greater proportion of coloured fruit than those on vigorous stocks.

While MM 106 is probably the most tested stock, Pink Lady on Ottawa, M 26, M 9, and M 27 have all produced excellent crops. However, it seems so far that Ottawa and Mark need a warm sunny climate to avoid a high incidence of FB. Similarly, M7 in some cooler locations has a high propensity to FB, but in warm locations this is not evident. There is a reluctance to use M 26, and M 9 in warm areas for fear that sunburn may be a problem. However some of the best Pink Lady in Europe are on M 9 grown in Spain and Southern France which have average summer temperatures exceeding those in the Goulburn Valley.
Pink Lady on low vigoured stocks which are allowed to suffer stress (to runt out) will produce fruit that have an increased susceptibility to FB.

[10]. AVOIDANCE OF TREE STRESS.
There is reliable evidence showing that stressed Pink Lady trees are likely to produce a higher proportion of fruit with FB than un-stressed trees. On the other hand the stressing of an over vigorous tree is an effective way to reduce vegetative growth, increase light penetration and colour, and increase sugar levels.
Cincturing and root ripping is a fashion in Australia at the moment but there is conclusive evidence that these treatments , while substantially reducing vigour, will increase FB on Pink Lady in CA storage.
Other forms of stress such as fungal root rots and less frequent irrigation schedules for stocks of less vigour than MM 106 can lead to an increase in FB with extended CA storage.
If over-vigorous trees are given anti-vigour treatments, fruit off such trees should be scheduled for short to medium term and not long term CA storage. The best way to control vigour is to operate at benchmark nutritional levels and to use the correct stock for the location.

SUNDOWNER mature only one week later than Pink Lady and need the same management parameters.