Developing guidelines for Ripe N Ready pear ripening

Dr Jason Johnston
HortResearch Ltd

Project Number: AP08045

AP08045

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the apple and pear industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the apple & pear industry.

ISBN 0 7341 1970 4

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

Know-how for Horticulture™

HAL Project No: AP08045 (31/03/09)

Developing guidelines for 'Ripe & Ready' pear ripening

Johnston J, et al

The New Zealand Institute for Plant & Food Research Ltd
www.plantandfood.com

HAL Project No: AP08045 (31/03/09)

Developing guidelines for 'Ripe & Ready' pear ripening

Dr Jason Johnston
Plant & Food Research, Auckland
Private Bag 92169, Auckland Mail Centre
Auckland 1142 New Zealand
Email JJohnston@hortresearch.co.nz
Tel +64 9 925 7247; Fax: +64 9 925 7001

Woolf A.
Plant & Food Research Auckland

Sharrock K.
Plant & Food Research Ruakura
Private Bag 3123
Waikato Mail Centre
Hamilton 3240 New Zealand

Moxham H.
Subcontracted consultant
23/14 Princes St
Newport NSW Australia

March 2009

STATEMENT OF INTENT

The final report for a project evaluating commercial ripening procedures for 'Ripe & Ready' pears.

FUNDING PROVIDED BY

Horticulture Australia Ltd
Apple and Pear Australia Ltd

Contents

Page

Media Summary

Consumer studies have demonstrated a higher preference for ripened pears over unripe pears. To exploit these preferences, the 'Ripe & Ready' and 'Perfectly Ripe' brands were established for Woolworths and Coles. The sale of pre-ripened pears was seen as a value adding opportunity for pear growers and packers by supplying 'Packham' pears with improved eating quality. However, surveys of fruit quality at retail outlets found major inconsistencies in ripeness and quality.

This project was initiated in 2008 to determine if current ripening procedures contribute to these inconsistencies. This was achieved by visiting and reviewing the ripening procedures of seven ripening facilities servicing retailers in Victoria, New South Wales and Queensland. These site visits revealed irregularities in temperature management, ethylene dosage, and monitoring of ripening. Immediate improvements could be achieved by implementing forced-air systems to warm the fruit before ripening treatment, and likewise to cool the fruit after ripening treatment. The ripening facilities are also yet to optimise the ripening temperature and ethylene dosage to produce an aromatic flavour and buttery texture characteristic of 'Packham' pears.

The different procedures used by ripening facilities will be contributing significantly to the variable ripeness and quality observed in retail outlets. Industry-wide improvements in ripening protocols are needed to improve the consistency of the eating experience by consumers, so that ultimately pear sales and prices can be lifted through increased consumer demand. We suggest workshops and working groups be established for pear ripeners and retail representatives to improve procedures for ripening, monitoring quality, inventory management, transport, retail presentation and waste management. We also recommend further research be undertaken to develop an optimised industry-wide protocol tailored for 'Packham' pears.

Technical Summary

Consumer studies have demonstrated a higher preference for ripened pears over unripe pears. To exploit these preferences, the 'Ripe & Ready' and 'Perfectly Ripe' brands were established for Woolworths and Coles in a supply window from June to December. The sale of pre-ripened pears was seen as a value adding opportunity for pear growers and packers by supplying 'Packham' pears with improved eating quality. However, surveys of fruit quality at retail outlets found major inconsistencies in ripeness and quality, which could be detrimental to the long-term reputation and success of this brand.

This project was initiated in 2008 to determine if inadequate ripening procedures contribute to these inconsistencies. This was achieved by visiting and reviewing the ripening procedures of seven ripening facilities servicing retailers in Victoria, New South Wales and Queensland. Key findings included:

- Inconsistent ripening procedures. There is currently no standardisation of the ripening procedure for 'Packham' pears. Current ripening procedures include: a) no ripening treatment, b) ripening at 20-25°C for 24-72 hours, and c) ethylene conditioning at 20-25°C for 24-72 hours.
- Ethylene conditioning. Four of the seven ripening facilities have ethylene ripening facilities, yet the full potential of ethylene conditioning is yet to be realised. Higher concentrations of ethylene could be used to produce ripe, aromatic 'Packham' pears early in the supply window.
- Conditioning temperatures. There is an opportunity to use lower ripening temperatures (e.g. 15-20°C) than those currently used in four facilities (23-26°C). The higher temperatures in current use could be exacerbating incidence of rots, stem-end shrivel, and skin yellowing.
- Coolchain management. Three ripening facilities used forced-air systems to warm the fruit before conditioning, while no facilities routinely used forced-air systems to cool the fruit after conditioning.
- Standards for ripeness. There is a perception amongst pear suppliers that the Coles standard of 2-4 kgf is too difficult to achieve, and concerns that it may increase the susceptibility to mechanical damage in transit. The Woolworths ripening standard is easier to achieve but does not appear to be monitored or enforced.
- Standards for external defects. There was a perception amongst pear suppliers that standards for external defects are too tough, and may need to be revisited. There was also a perception that the ripening treatment may worsen the appearance of some skin defects.

Conclusion: The lack of consistent ripening procedures across the industry is very likely to contribute significantly to the variation in ripeness experienced in retail outlets. Improvements in ripening procedures are needed to improve the eating experience and increase the consumer demand needed to lift pear sales and prices.

Key recommendations:

- Implementation of forced-air warming and cooling systems to produce a more even ripening response
- Establishment of working groups and workshops for ripeners and retail representatives to improve procedures for ripening, monitoring quality, inventory management, handling during transport, retail presentation and waste management
- Devising an industry strategy for clearly differentiating pre-ripened pears in supermarket displays and for enforcing standards to protect the reputation of the brand
- Research to develop a standardised industry-wide ripening protocol tailored to specific ripening characteristics of 'Packham' pears, and to clarify consumers tolerance to external defects.

Introduction

Consumers of European pears are increasingly showing a preference for pre-ripened fruit (Villalobos-Acuna & Mitcham 2008; Poelman & Forde 2006; Poelman & Gray 2007). Surveys in US markets found that partially ripe 'William bon Chrétien/Bartlett' outsold the unripe counterparts by three to one (California Pear Advisory Board 2004). In 2000, Apple and Pear Australia Ltd (APAL) commissioned a major survey of pears to determine consumer preferences, which included 'Packham' and 'Buerre Bosc' (Dignam 2000). Consumer panels were used to evaluate each cultivar and a range of count sizes, textures, sugar concentrations, skin condition and firmness. The potential for increasing the consumer acceptability of 'Packham' pears in Australia was also shown from consumer studies where a higher preference was shown for ripened pears when consumers were presented with fruit at different stages of ripeness (Poelman & Forde 2006; Poelman & Gray 2007). These detailed studies resulted in the introduction of 'Ripe & Ready' initially through Cole's supermarkets in 2002, currently branded as 'Perfectly Ripe', and latterly through Woolworths, branded as 'Ripe & Ready'. However, a recent survey of pears sold under these brands showed a large variation in firmness in retail outlets, with some fruit too firm (7.8 kgf) to be considered pre-ripened (Poelman & Forde 2006). The causes of these inconsistencies are not known, but inadequate conditioning procedures for triggering ripening are likely to be a contributing factor.

The successful implementation of 'Ripe & Ready' is seen as an important strategy for increasing domestic pear sales in Australia, and for commanding a premium price from consumers. The current domestic pear marketing programme aims to implement strategies that increase pear consumption from 3.8 kg to 4.3 kg per capita, while at the same time improving the average wholesale price to greater than $1.41 per kg (Apple and Pear Australia Ltd 2007a). However, it is unlikely that consumers will pay a premium for ripened pears if the current variability in firmness is such that consumers are disappointed and the fruit fail to meet expectations. These consumers are also unlikely to show brand loyalty and re-purchase these pears on an ongoing basis, as they may perceive the fruit quality/ripeness as not sufficient to merit such loyalty. For 'Ripe & Ready' to be successful in the long term, there is a need to deliver consistent quality fruit throughout the season, and to deliver a level of ripeness that meets consumer expectations.

'Packham' is the principal pear cultivar for fresh consumption in Australia, filling the market window in June at the completion of 'William bon Chrétien/Bartlett' sales, through to December. The long storage potential of 'Packham' pears, particularly when stored in controlled atmospheres, makes this cultivar suited to supply markets through to December. Other important cultivars such as 'William bon Chrétien/Bartlett' have a shorter storage life (three months), making this cultivar less suited to the June to December market window.

Consumer support for pears decreases during the transition between 'William bon Chrétien/Bartlett' and 'Packhams', largely because soft and juicy 'William bon Chrétien' are being replaced by overly firm 'Packham' that ripen slowly in the fruit bowl or may not ripen at all, resulting in consumer dollars and product loyalty migrating to other fruits. Implementation of optimised conditioning procedures for early 'Packham' should improve fruit acceptability and consumer loyalty during the transition between cultivars, with only a minor decline in sales. However, the variation in firmness evident in retail outlets suggests the current ripening protocols may not be effective at delivering the consistency and quality of pears expected by consumers.

This project determined whether variation in the current ripening procedures for 'Packham' contributes to the inconsistencies in firmness and quality observed in retail outlets. This was achieved by visiting seven ripening facilities in three locations in September/October 2008, with ripening facilities chosen on the basis of being large suppliers of pears. The information obtained from each ripening facility is presented in a manner that maintains anonymity. Each pear supplier was given the opportunity to view and comment on our interpretation of their ripening protocol before its inclusion in this report.

Project objectives:

- Determine consistency of ripening procedures between ripening facilities
- Provide recommendations to individual ripening facilities for improving ripening and quality monitoring procedures
- Produce a preliminary industry-wide protocol for ripening ‘Packham’ pears
- Identify opportunities for implementing new technologies/techniques for ripening and monitoring pears.

Current ripening procedures for 'Packham' pears

Following visits to seven ripening facilities it was evident that three different conditioning procedures were used to trigger the ripening of pears (Table 1). These included:

1. No conditioning – one facility
2. Conditioning using elevated temperature – three facilities
3. Conditioning using elevated temperature and ethylene – three facilities.

Ripening facility D was supplying 'Ripe & Ready' pears, but weren't performing ripening treatments. This supplier thought there was no need to condition the pears, and check the firmness, if the supermarket doesn't enforce the firmness standard. On this basis they felt it was only necessary to meet the standards related to appearance.

Amongst the other ripening facilities, there were also inconsistencies in the methods of warming before conditioning, the temperature during conditioning, and the operation of ethylene delivery equipment, the details of which are presented in the following sections.

Table 1. Summary of conditioning procedures for triggering ripening of 'Packham' pears

Ripening facility	Warming method before conditioning	Set temperature during conditioning	Ethylene used during conditioning	Ethylene concentration during conditioning	Cooling method after conditioning
A	Passive[1]	18-20°C	No	-	Passive
B	Forced-air	24°C	No[2]	-	Passive
C	Passive	25-26°C	No	-	Passive
D[3]	-	-	-	-	-
E	Passive	24-25°C	Yes	25 ppm	Passive
F	Forced-air	22-24°C	Yes	12 ppm	Passive
G	Forced-air	18-19°C	Yes	Not known	Passive

[1] Passive means warming/cooling in rooms with standard evaporator fans
[2] Has equipment for ethylene treatment, but it is no longer used. They perceived no advantage over temperature-only conditioning
[3] This facility supplies 'Ripe & Ready' pears but does not perform ripening/conditioning treatments. They attempt only to meet standards for appearance

Warming before conditioning

Three facilities used forced-air warming while the other facilities relied on passive warming to increase the temperature of pears before conditioning (Figure 1). Forced-air warming systems are preferable as they ensure a more even rate of warming between and within pallets of fruit (Maxie et al. 1974; Villalobos-Acuna & Mitcham 2008). The inadequacies of passive warming were evident during a visit to one facility, where large discrepancies in skin temperatures of 5°C to 19°C were measured using an infrared thermometer amongst fruit held in the same room for 24 hours with a set temperature of 24-25°C. In this instance the evaporator fans being turned off compounded the problem. Fruit with skin temperatures of 19°C were found closest to the heaters and minor sources of air circulation, while the 5°C skin temperatures were recorded at the bottom of the pallet stack in the centre of the room. These measurements were recorded from fruit positioned on the outside of the pallet stack, making it likely that even colder temperatures could have been present in the centre of the pallet. This large variation in fruit temperature will produce an uneven ripening response within the room, resulting in variable firmness that may persist through the supply chain.

The importance of uniform warming rates was highlighted in a study on bin stored 'William bon Chrétien/Bartlett', where variation in warming rates of 2 days for different locations in the bin resulted in a 5-7 day variation in ripening time according to firmness (Maxie et al. 1974). This variation in firmness will go largely undetected by the ripening operators, as personnel often sample easily accessible fruit from the top of pallets, or from parallel library sample trays, rather than those positioned at the bottom-centre of pallets. The use of forced-air systems to warm the fruit uniformly should ensure a more even ripening response, and make those fruit sampled for firmness more likely to be representative of all the fruit in the room.

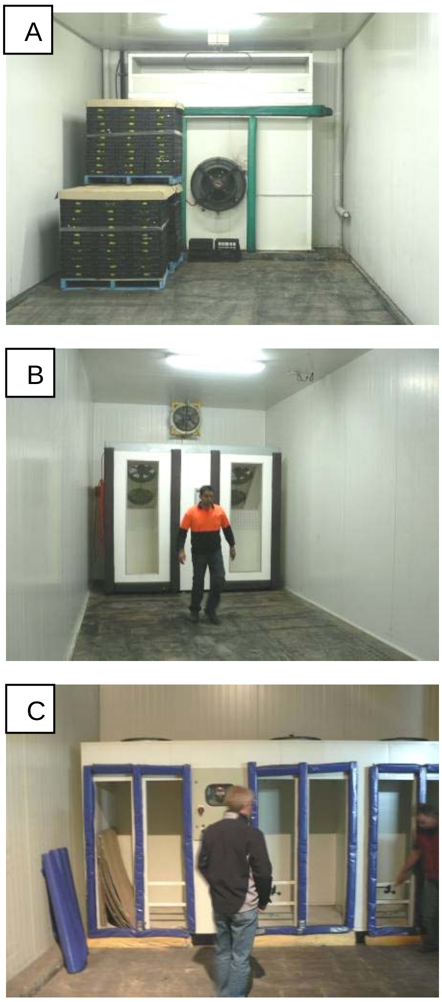

Figure 1. Forced-air systems currently used to rapidly warm pears for conditioning treatments. System A is a single fan system that requires two rows of pallets either side of the fan. Air flow is created through the sides of each pallet by placing a cover over the top and end of both rows of pallets and keeping the sides open. Systems B and C comprise a series of 2-3 fans, each of which can be operated independently by placing one row of pallets directly in front of the fan. Air flow is created either i) through the sides by covering the top and end of each individual row of pallets, or ii) through the end by covering the top and sides of each row of pallets.

Temperature during conditioning

The next layer of inconsistency amongst the ripening facilities was the set temperature in the ripening room. Two ripening facilities had rooms set at 18-20°C, while the other facilities had rooms set at 24-26°C. There is currently no publicly available information as to what the optimal temperature is for conditioning 'Packham', but it is possible that these discrepancies may be contributing the inconsistency in quality in the marketplace. An increase in the ripening temperatures from 15-20°C to 24-26°C may have the following effects:

- More rapid ripening rate (Villalobos-Acuna & Mitcham 2008), which may shorten the shelf-life

- Development of a mealy texture rather than a buttery, juicy texture (Hansen & Mellenthin 1979)
- Accelerated yellowing of the skin relative to softening (Hansen & Mellenthin 1979)
- Increased rots, water loss and stem-end shrivel.

Ripening protocols developed for winter pears in the United States of America (USA) generally recommend a ripening temperature of 15-21°C (Hansen & Mellenthin 1979), and recommend not exceeding 23°C when using ethylene (California Pear Advisory Board 2004). Until the optimum ripening temperature has been experimentally determined for 'Packham', it is recommended that all ripening facilities use a ripening temperature between 15 and 21°C. Two ripening facilities currently operate within this range (18-20°C). It is also recommended that ripening operators monitor the core fruit temperature as well as the evaporator return air temperature during ripening.

Cooling following conditioning

This was one aspect that was consistent across all ripening facilities, in that nearly all fruit were passively cooled following conditioning, by placing the fruit in coolstores with moderate airflow associated with standard evaporator fans. In all cases the ripening facilities wanted to achieve a target temperature of 2°C before refrigerated transportation to regional distribution centres. However, improvements in the rate of cooling and uniformity of cooling could be achieved using forced-air cooling, the same units used by some facilities to warm the fruit. Uniformity of cooling is important to minimise variation in firmness that could persist through the supply chain. Rapid cooling is also important for slowing the rapid rates of ripening and water loss established in the ripening room, so that the risk of over-ripening and stem-end shrivel is minimised during distribution and retail display. Rapid cooling following ripening is of particular importance following the use of ethylene, as these fruit tend to have a high ripening rate and could deteriorate quickly during distribution if allowed to remain at elevated temperatures.

Ethylene conditioning

The use of ethylene was another inconsistency amongst the ripening facilities. Four facilities had ethylene treatment capability, with one of these four choosing not to use ethylene as they perceived no difference over temperature-only conditioning treatments. Of the three facilities that did not have ethylene treatment equipment, one operator commented that "using ethylene is like playing with fire" and couldn't see a need for it, while another would like to see a cost/benefit analysis of using ethylene before considering installation of the equipment.

Ethylene treatment is considered beneficial for synchronising ripening and overcoming the high ripening resistance (chilling requirement) of pears early in storage (Chen et al. 1996). There is also sensory evidence that ethylene treatment may improve the ripe-flavour characteristics of 'Anjou' (Chen et al. 1996). While there is limited publicly available information on the ethylene responses of 'Packham', there is no evidence that precludes these benefits from also occurring for 'Packham'. Ethylene treatments in the USA were originally performed for fruit early in storage to overcome the chilling requirement (< 3 weeks of storage for 'William bon Chrétien/Bartlett', < 8 weeks of storage for 'Anjou'), before resorting to temperature-only conditioning for longer stored fruit (Chen et al. 1996; Villalobos-Acuna & Mitcham 2008). The enhanced sensory characteristics of ethylene-treated pears has led to increased supply of ethylene-treated pears later into the season, with the length of the ethylene treatment period being reduced as the season progresses (see section on ethylene conditioning in the USA). In contrast, the Australian ripening facilities using ethylene tend to use a much lower concentration of 12-25 ppm than the USA (at least 100 ppm), and tend to use ethylene constantly throughout the season. In this respect it seems that full potential of ethylene treatments has not been realised by the Australian pear industry, as the current ethylene concentration and approach may contribute to over-ripening of late-season fruit, and be ineffective in releasing the full ripening potential of early season fruit. Ethylene concentrations similar to those used in USA could be used to ripen early season 'Packham' to produce consistently a more aromatic pear to follow on from 'William bon Chrétien/Bartlett'.

Of the ripening facilities visited with ethylene treatment equipment, two were based on a real-time system that monitors the ethylene concentration in the ripening room and adds ethylene as required to maintain a set concentration (Figure 2, Appendix B). The other system, also installed in two facilities, is based on a pulse delivery system, where predetermined volumes of ethylene are injected into the ripening room at predetermined time intervals (Figure 3). This latter system does not have the capacity to monitor actual ethylene concentrations in the room, with the pulse intervals and volumes predetermined by the system installers. Of the two systems, we recommend the real-time monitoring and delivery system, as this system gives the operator more control and traceability of the ethylene concentration present during the ripening process. While initial capital cost may be higher, there are savings on labour and health and safety benefits.

Figure 2. Real-time ethylene monitoring and delivery equipment installed in two ripening facilities. The system uses RipeGas® (BOC Limited) as a dilute form of ethylene (≅ 6-8%), and monitors and controls CO_2 to prevent accumulation to quantities that may be dangerous to personnel and cause damage to fruit.

Figure 3. Pulse ethylene delivery equipment installed in two ripening facilities. The system passes pure ethylene through a water tower to mix and humidify the gas. Ethylene pulses are delivered at intervals predetermined by the system installation staff. This system does not monitor the actual ethylene concentrations in the ripening room.

It was apparent from visits to ripening facilities that there were inconsistencies in advice given on the optimal ethylene concentration for ripening pears. Concentrations to date seem to have been derived through internal trial and error, advice from Coles (recommendation is 12 ppm), or by accepting the concentration set up by the installation/maintenance company. In this respect, one ripening facility was using ethylene, but did not know what concentration they were using. The set ethylene concentrations for the other two ripening facilities ranged from 12 to 25 ppm, which is comparatively lower than those concentrations recommended in the USA of 100 ppm (California Pear Advisory Board 2004; Pear Bureau Northwest 2004; Villalobos-Acuna & Mitcham 2008).

The importance of monitoring actual ethylene concentration rather than relying on set ethylene concentration was highlighted in gas samples taken from one ripening facility, where the set concentration was 25 ppm but the actual concentration was 0.8 ppm. This large discrepancy could be explained by the presence of other gases found during the analysis for ethylene (Figure 4). The identity of these gases has not been verified, but they are likely to result from the forklift exhaust gases produced during room loading. The providers of the ethylene monitoring and delivery system acknowledge that exhaust gases will interfere with the sensor, and recommend that operators check the system is reading “0” before starting the system. If operators have not been checking this operational aspect, it is possible that large discrepancies in the actual ethylene concentration could occur between ripening runs.

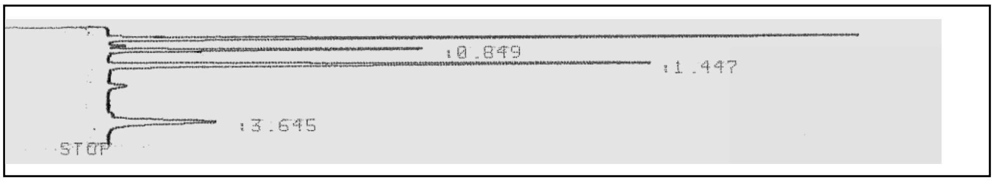

Figure 4. Chromatogram of gases collected from a ripening room 24 hours after initiation of ripening treatment. Peak 0.849 (second from top) is ethylene as confirmed by spiking the sample with a pure ethylene standard. The bottom two peaks are unidentified but are most likely to be associated with forklift exhaust emissions during loading of the room.

Gas samples were also taken from one ripening room using ethylene to determine the CO_2 concentrations during ripening. The accumulation of CO_2 is dangerous from a human health perspective, but also in that it may damage the fruit and impede the ripening process. The gas sample was taken from a room equipped with a monitor for CO_2 that could operate a vent if concentrations exceeded 1%. Analysis of the gas sample revealed a low CO_2 concentration of 0.15%, a concentration well below the set threshold of 1%. The extent of CO_2 accumulation will differ between ripening rooms, according to fruit respiratory rate, fruit temperature, the amount of fruit in the room, the leakage/venting rate of CO_2 from the room, and whether CO_2 scrubbers are present. In this respect, the value of 0.15% CO_2 cannot be considered representative of all ripening rooms, but this value did demonstrate that CO_2 concentrations probably are not an issue for this ripening facility and are unlikely to be causing variation in the ripening response.

Observations and recommendations for individual ripening facilities

The following recommendations were made to individual ripening facilities. No recommendations were made to facility D, as they were supplying 'Ripe & Ready' pears but were not performing conditioning treatments.

Ripening facility A

- Implementation of a forced-air system to warm the fruit rapidly and uniformly before temperature-only conditioning, and likewise to cool the fruit following conditioning.
- Consider positioning the library sample for monitoring ripening and quality in the same room as the pallets of fruit to minimise differences in temperature, relative humidity and ethylene concentration between the library and "real" fruit.

Ripening facility B

- Implementation of a forced-air cooling to reduce variability in cooling rates and quality after the conditioning treatment. This facility already uses a forced-air system to warm the fruit; this same system could be used to cool the fruit if it can be easily moved to a cold-room.
- The ethylene ripening system was not in use at the time of the visit, but was connected to a bottle of pure ethylene. To reduce the risk of explosion we recommend the cylinder be located outside the packing shed, or the bottle be swapped for the safer and more dilute form of ethylene sold as RipeGas® (see Figure 2).

Ripening facility C

- Implementation of a forced-air system to improve uniformity of warming between pallets before temperature conditioning, and likewise to achieve rapid and uniform cooling before transport.
- The ripening room was not equipped with sufficient fans to ensure even fruit temperature between and within pallets.
- Consider positioning the library sample for monitoring ripening and quality in the same room as the pallets of fruit to minimise differences in temperature, relative humidity and ethylene concentration.

Ripening facility E

- Implementation of a forced-air system to improve uniformity of warming between pallets before ethylene conditioning, and likewise to achieve rapid and uniform cooling before transport. The uneven warming was highlighted by infrared temperature measurements in the ripening room (which had been sealed for 24 hours), where external fruit temperatures ranged from 19°C in the rear of the room, to 5°C in the middle of the room. There were also large temperature differences between the bottom and top of the pallet. In the short term it is recommended that the evaporator fans be left on during the ripening treatment, and in the long term consideration given to investing in a forced-air system for warming and cooling the fruit.
- Gas samples were taken during the visit to check the actual ethylene concentration in a ripening room programmed to deliver 25 ppm, 24 hours after the treatment had started. Ethylene was detected in the ripening room using the Gastec® cartridge system, although the concentration was difficult to evaluate given that the cartridge produced a diffuse colour change. Analysis of gas samples collected in glass jars and transported back to New Zealand showed that the ethylene concentrations were low (0.7-0.85 ppm), and that the samples contained a large number of other hydrocarbon contaminants (probably from forklift exhaust fumes, see Figure 4). These contaminants are thought to be the main

reason why the portable cartridges gave a diffuse colour change. It is also possible that these contaminants may be affecting the accuracy of the ethylene delivery system, as the measured ethylene concentrations were lower than the concentration displayed by the unit. This low dose is probably suited to late storage 'Packham' (which have a low ripening resistance), but may not be effective at triggering ripening in early season pears (which have a higher ripening resistance). These gas impurities are much less effective at triggering ripening than ethylene.

- CO_2 levels were low in the ripening room, as determined by the portable Gastec® cartridges (< 0.25%) and by using more accurate equipment (0.15-0.17%).

Ripening facility F

- A more uniform warming could be achieved from the forced-air system if the cardboard system were replaced with a tarpaulin that covers the top and end of the pellet rows.
- A more uniform and rapid cooling following ripening treatment would be achieved through the use of forced-air cooling (the same equipment as that already used to warm the fruit).
- The ethylene plumbing system could be shortened so that the pipe work goes directly through the wall from the delivery system, rather than the current system which goes up the wall, over the top and down the other wall. This shortening would reduce leakage, and also make the system more responsive to the concentrations inside the room (e.g. to increase sooner and be less likely to overshoot).

Ripening facility G

- A high incidence of superficial scald was observed following ripening treatment. This is not caused by the ripening treatment or facilities, but is a reflection that the diphenylamine (DPA) drench and controlled atmosphere (CA) storage conditions were ineffective at controlling this disorder before the fruit were delivered to the ripener. This problem could be reduced by reducing storage times (not possible in high volume seasons), optimising the oxygen levels in CA (ultra-low O_2 can reduce incidence of superficial scald), investigating the potential for SmartFresh℠ treatment, and optimising DPA drenching protocols to ensure timing and dosage are correct.
- The ethylene delivery system was attached to a cylinder of pure ethylene located inside the building. This increases the risk of explosion, and on this basis we recommend that the cylinder be relocated outside, or preferably that the less pure form of ethylene be used (RipeGas®, 6-8% ethylene).
- The risks of explosion and/or inaccuracy of delivering predetermined ethylene concentrations are also compounded by the choice of plumbing tubing and connections, which can be prone to leakage (Figure 5).
- Implementation of forced-air cooling to achieve a more rapid and uniform cooling after ripening. This will be critical for late season fruit which can advance rapidly once ripening has been triggered.

Figure 5. Non-optimal plumbing for pulse delivery ethylene system.

Monitoring ripening, quality and postharvest environmental factors

Monitoring of ripening, general fruit quality, and environmental conditions before, during and after conditioning, are all important for delivering a uniform product to retail outlets. This information can be used to ensure consistency of individual conditioning treatments, and be related to out-turn reports as a means of improving procedures if required.

Monitoring fruit ripening and quality

All the ripening facilities monitored flesh firmness during conditioning using an Effegi penetrometer (Figure 6). Some facilities previously used a non-destructive Sinclair system to allow repeated measurements over time, but at the time of the visit all had reverted to the penetrometer. There were some inconsistencies in the units recorded from the penetrometer, in that two of the seven ripening facilities worked in lbf while the others worked in kgf. Most ripeners thought there was no confusion over which units should be used, although one of the ripeners working in lbf had encountered some confusion. To ensure industry-wide consistency, we recommend that kgf be implemented as the standard unit.

Figure 6. Drill press-mounted Effegi penetrometer. Use of a drill press helps to reduce user-to-user variability and fatigue.

Ripening facilities differed in their approaches to monitoring firmness during conditioning (Table 2), in that two of the facilities held the pears for firmness measurement in a location separated from the ripening room. It is likely that the temperature, relative humidity, ethylene concentration and CO_2 concentration will differ between locations, raising the possibility that the ripening rate of the sample may not reflect that in the ripening room. Of those facilities that sampled fruit directly from the ripening room, two sampled from a dedicated tray located close to the door for easy access, while the other two sampled fruit directly from the tops of pellets. We recommend that firmness be measured on fruit located in the ripening room, and be sampled from multiple locations in the room to account for temperature gradients, so that an accurate estimate of firmness for the whole room is determined. The need to sample from multiple locations is higher for fruit that have not been forced-air warmed, as these rooms will contain fruit with highly variable ripening responses. Only three facilities were sampling an acceptable number of fruit to estimate firmness (e.g. 25-30 fruit), while three weren't sampling a sufficient number of fruit (<15). The sample size is not only important for determining the average firmness (e.g. to meet standards), but also to determine the variability in firmness. If the sample has high variability in firmness, it suggests the conditioning treatment is not sufficient to synchronise the ripening response. It is possible that the variability in firmness of

'Ripe & Ready' pears in retail outlets could be reduced if suppliers could reduce the level of variability in firmness after conditioning.

Table 2. Summary of sampling procedures for monitoring firmness during conditioning of 'Packham' pears

Ripening facility	Fruit assessed for firmness per batch	Location of fruit samples for firmness
A	30	Separate room
B	25-30 (1 tray)	In the ripening room but in a separate tray
C	12-13	In a plastic bag placed on a shelving unit located outside the ripening room
D[1]	-	-
E	25-30 (1 tray)	In the ripening room in a separate tray
F	9 (3 fruit on 3 occasions)	Sampled from top of pallet
G[2]	3-5 (1 per day)	Sampled from top of pallet

[1] This facility supplies 'Ripe & Ready' pears but does not perform ripening/conditioning treatments nor monitor firmness; they attempt only to meet standards for appearance.
[2] Also assesses firmness on a wider sample of fruit by hand.

The ripening facilities all monitored general fruit quality after conditioning, checking for firmness, soluble solids (% Brix), skin defects, mechanical damage, and flesh browning. An important aspect of monitoring fruit quality is to ensure any defects are categorised correctly. In this respect, superficial scald looks similar to friction marks, yet these defects are caused by completely different factors. One ripening facility thought that some retailers may struggle to differentiate these two forms of defects, making it difficult for suppliers develop appropriate corrective actions for future shipments/seasons. The other key aspects of monitoring quality are to ensure the equipment is calibrated regularly, that training is provided to new operators, and procedures are regularly reviewed to reduce the chances of producing inaccurate results. Calibration and operational procedures for penetrometers and refractometers can be found in Watkins & Bartsch (1997). There are also opportunities for implementing new technologies for monitoring aroma-flavour related aspects of ripening; an example of this would be the ripeSense® sensors (www.ripesense.com).

Measuring temperature

Since fruit temperature is so important to achieving a high quality product, it is important to pay careful attention to set temperatures, and, importantly, to variability between and within pallets.

An important tool in monitoring temperature is an accurate, calibrated hand-held digital thermometer equipped with a robust metal probe. The resolution should be to 0.1°C if possible, and calibration should be carried out regularly (every 2-3 months or when the unit is dropped). Ice-point calibration is the simplest and cheapest method. This is carried out by placing the probe in a slurry of ice and water for 10 or so minutes. The temperature should read 0.0°C. Examples of units we have found to be robust and reliable can be seen at http://www.argus.co.nz/Thermometers.html.

Infrared thermometers can also be of use for rapid non-destructive measurement of surface temperature. It should be noted that temperatures are generally less accurate, generally ± 1 or 2°C. An example of a suitable infrared thermometer is shown in Figure 7 and a range viewable at: http://www.omega.com/toc_asp/sectionSC.asp?section=J&book=temperature.

Figure 7. Example of infrared thermometer for measuring surface temperature.

Measuring ethylene

Key times to measure ethylene are ≅ 30 minutes after injection of the ethylene (to determine initial ethylene concentration), at 24 hour intervals (to determine how quickly the ethylene concentration increases and stabilises) and at the end of the treatment period (to determine the final concentration and thus leakage rates).

A range of commercial services are generally available in fruit-growing regions for monitoring of ethylene concentration. Other ways of measuring ethylene concentration involve the use of handheld systems. The Gastec® syringe system (Figure 8) is a relatively simple and cheap tool using disposable glass tips (≅ $10/measurement), and CO_2 concentration can also be measured (with a different tip). Digital hand-held ethylene measuring devices are also available, such as the Pac III Single Gas Detector from Draeger Safety (Figure 9), but may be beyond the budget of many (≅ A$ 800).

Figure 8. Gastec® syringe system.

Figure 9. Digital hand-held ethylene measuring device.

It should be noted that one of the ethylene ripening systems available from Australia (the GT Automatic Fruit Ripener® from Controlled Ripening Systems Australia Pty Ltd – see Appendix B and Figure 2) also doubles as a way of measuring ethylene concentration, since it possesses an ethylene sensor and displays the concentration on a screen. Note also that other hydrocarbons (e.g. byproducts of non-electric forklifts) may lead to higher apparent concentrations (see Figure 4).

Harvest maturity and storage protocols

Harvest maturity, storage conditions, and storage duration have a strong influence on the ripening resistance of pears (Villalobos-Acuna & Mitcham 2008). Ripening resistance tends to decline during the harvest window and continues to decline during storage. The use of controlled atmospheres and SmartFresh^{sm} to extend storage life also delays this loss of ripening resistance. Most of the fruit used for 'Ripe & Ready' are stored in controlled atmospheres to enable supply through to December, while SmartFresh^{sm} is yet to be considered for 'Packhams'.

Variable ripening rates induced by maturity and storage factors can be considered problematic if these factors aren't managed, but there is scope to exploit these factors to manage ripening times during a prolonged supply season. Fruit harvested less mature tend to have a higher storage potential and be more responsive to controlled atmospheres, making these fruit more suited to long-term storage. In contrast, fruit picked more mature are more suited to short-to-medium term storage. In this respect, decisions could be made at the time of harvest as to whether the fruit is suited to short, medium or long-term storage, and then if possible load the controlled atmosphere rooms so that all long-term storage fruit are stored together. By using this system, it should reduce the problem of ripeners handling immature pears with high ripening resistance early in the season, and likewise reduce the chances of handling over-mature pears with low ripening resistance later in the season.

The success of a maturity-based differentiation system for storage potential will be determined by the maturity monitoring procedure in the orchard, an adherence to maturity standards, and an awareness of risk for other aspects of quality such as storage disorders. Early harvest fruit can be prone to superficial scald, which can be reduced by ensuring the fruit aren't picked too immature, and by ensuring diphenylamine drenching protocols are effective and adhered to (Apple and Pear Australia Ltd 2007b). Likewise, late harvest fruit can be susceptible to senescent flesh browning. Therefore, if harvest maturity is to be used as a basis for determining storage potential and ripening resistance, caution is required to ensure that maturity boundaries aren't pushed to an extent that disorder risk is heightened. The current maturity standards may not be sufficient to reduce some of the outturn risks associated with ripening treatments. In this respect, there is need to determine appropriate maturity standards for 'Ripe & Ready' pears.

The risk of developing rots, shrivel, disorders, and an over-ripe appearance increases with storage time. This risk window is highest from September onwards. Two approaches can be taken to manage this risk, the first being to increase sales earlier in the market window (June to August) by implementing more effective ethylene-based ripening protocols. The second approach is organise the inventory so that fruit more at risk of developing these problems are sold earlier in the season. Maturity will be a key factor for determining risk, but there is also a likelihood that some orchards historically have a higher risk of developing problems irrespective of harvest maturity.

Preliminary industry-wide ripening protocol for ‘Packham’ pears

The limited availability of published information on the conditioning response of ‘Packham’ means the following ripening protocol can be considered only preliminary and requires further experimentation and possible modification to make it sufficiently robust to warrant becoming embedded as an industry-wide protocol. While some aspects of the protocol are cultivar-generic, such as the benefits of forced-air warming and cooling, others such as the optimum conditioning temperature and ethylene dosage are likely to be cultivar-specific, and will need experimental confirmation.

1. Pack, palletise, and load the fruit into a ripening room set to deliver a core fruit temperature of 18-20°C, and maintain a relative humidity of 90-95%.
2. Use a forced-air system to warm the fruit uniformly and rapidly to 18-20°C, and hold the fruit at this temperature for 12-24 hours before applying the conditioning treatment. This step is needed to ensure an even ripening response following conditioning.
3. Options for conditioning treatments to trigger ripening:
   a. Temperature-only conditioning for fruit stored longer than 4 weeks (to ensure the chilling requirement is satisfied) – maintain the fruit at 18-20°C until the fruit have softened to 5-6 kgf. This allows for a 1-2 kgf drop during transportation, with a delivery firmness of 3-4 kgf to meet Coles specifications. Note – further experimentation is required to verify that 5-6 kgf is an appropriate post-conditioning firmness for ’Packham’ to meet the shelf life requirements of supermarkets. The USA recommendation for ‘William bon Chrétien/Bartlett’ is to ripen the fruit to no less than 4.5-5 kgf at the point of distribution (California Pear Advisory Board 2004). We have recommended a slightly higher firmness of 5-6 kgf to account for conditioned ‘Packham’ in Australia needing to be transported large distances.
   b. Ethylene conditioning for early season ‘Packham’ (pre July) – apply 100 ppm ethylene for 1-3 days, or until the fruit have softened to 5-6 kgf. Note – this recommendation is based on that used for ‘William bon Chrétien/Bartlett’ and ‘Anjou’ in the USA (California Pear Advisory Board 2004; Villalobos-Acuna & Mitcham 2008). Further experimentation is required to confirm the dosage and duration, and also to determine benefits of ethylene conditioning for mid-to-late season ‘Packham’.
4. Monitor the CO_2 concentrations in the ripening room for all conditioning options, vent if the concentrations exceed 2%, and re-establish the ethylene concentration if using ethylene conditioning. Studies with ‘Anjou’ suggest that this cultivar can tolerate CO_2 concentrations up to 10% during conditioning treatments (Sharrock, Personal Communication). However, until the CO_2 tolerance of ‘Packham’ is determined, and to reduce the health and safety risks associated with high CO_2, we recommend concentrations should not exceed 2%.
5. On completion of conditioning, vent the ripening room to ensure residual ethylene and CO_2 do not affect the conditioning response of following batches of fruit. Also be mindful of proximity of other ethylene-sensitive products near the ripening room, to ensure these crops are not inadvertently exposed to ethylene during venting.
6. Use a forced-air system to cool the fruit uniformly and rapidly to 0-2°C before transportation. This step is critical for minimising variation in ripening rates following conditioning so that a consistent product is delivered to retailers. Rapid cooling is also needed to slow the progress of ripening to ensure the fruit have sufficient shelf-life.

Ethylene conditioning in the USA

Using ethylene conditioning to increase pear sales

Demand from US supermarkets for conditioned pears has increased almost logarithmically since very small beginnings in 2001. The Pear Bureau Northwest (PBNW 2004) estimates that currently 40-50% of the 'Green dAnjou' crop and 7% of the 'William bon Chrétien/Bartlett' grown in the Pacific Northwest are being conditioned before reaching domestic retail shelves. One major chain (Kroger) now stipulates that all 'Anjou' pears must be conditioned before supply. A 30% increase in Kroger's sales of 'Anjou' in 2004 relative to 2003 was attributed to conditioning. Other chains are reporting 25-50% increases in pear sales when adding conditioned pears. Walmart has seen repeated double-digit growth in their pear category through their in-house conditioning programme.

Some chains are pricing slightly higher for conditioned pears, and some packers are paid a premium of US $2 per carton. The ultimate reward is good repeated business by the consumer, which shows the retailer the value of buying from a shipper who conditions well with ethylene.

Branding of ethylene conditioned pears

The Pear Bureau is not branding any particular ripe pear programme. Rainier promotes Blue Star's pears as "Extra Sweet" and "Extra Juicy" on their labels. Stemilt has also advertised their ripening programme as well. See Figure 10 for examples of the advertisements.

Figure 10. USA pear advertisements for ethylene-conditioned pears.

Regulation of supply of ethylene conditioned pears

Currently the only regulation imposed by the Fresh Pear Marketing Committee that has some bearing on conditioning of Anjou is:

§927.316 Handling regulation.
During the period August 15 through November 1, no person shall handle any Beurre D'Anjou variety of pears for shipments to North America *(Continental United States, Mexico or Canada)*, unless such pears meet the following requirements:
(a) Beurre D'Anjou variety of pears shall have a certification by the Federal-State Inspection Service, issued prior to shipment, showing that (1) the core/pulp temperature of such pears has been lowered to 35 degrees Fahrenheit or less and (2) any such pears have an average pressure test of 14 pounds or less.
(b) Each handler may ship on any one conveyance 8,800 pounds or less of Beurre D'Anjou variety of pears without regard to the quality and inspection requirements in paragraph (a) of this section.

This is intended to restrict the market-damaging practice of attempting to sell substantial quantities of 'Anjou' early in the season, before their chilling requirement has been satisfied, meaning that they will not ripen acceptably without external ethylene. It was presumably not expected to restrict responsible conditioning practices, since few, if any, packers would consider releasing "conditioned" fruit that had not fallen below 6.4 kgf average firmness during the process. However, if enforced strictly, the regulation could have an impact on those packers who prefer to ship warm (>1.6°C) fruit after conditioning, relying on some continuing in-transit conditioning as they gradually cool in the truck.

There is no external auditing to ensure that Pear Bureau pear conditioning guidelines are met. The Pear Bureau is currently in the process of reviewing and developing best practices for conditioning that it is hoped the industry will adopt. There is also talk of certification, but the industry appears unlikely to be ready for this step. Early in the season it is patently obvious if pears, particularly 'Anjou', have not been adequately conditioned. Either they remain unripe for weeks at room temperature if given no conditioning whatsoever, or sub-optimal conditioning can trigger softening, but leave fruit markedly deficient in flavour and aroma. From January onwards, it becomes much more difficult to distinguish conditioned from untreated fruit after ripening, by any test that is not based on taste or aroma. At this stage fruit have the capacity to produce their own ethylene, so it is tempting for packers to supply "conditioned" fruit that in fact have received no artificial ethylene treatment, and, at most, may simply have been warmed briefly before shipping.

Specifications from the buyers for conditioned pears vary widely between chains. A survey that aimed to determine the visible and edible quality of Pacific Northwest pears from the 2003 harvest in retail markets across the USA found that pears sold as "ready-to-eat" ranged in firmness from 0.7 to 5.9 kgf one day after purchase (E. Kupferman, pers. comm.). Kroger does not specify set minimum specifications for conditioned 'Anjou', but the pears arriving at its distribution centres average 3.6 kgf in firmness, and 1.8 kgf in-store on display. They aim to sell pears that are ripe and will be ideal eating quality (which most would agree is around 0.9 kgf firmness) within two days after the consumer has purchased the fruit. Other retailing chains are much more cautious. Safeway specifies a minimum of 4.5 kgf on arrival, and Costco stipulates 5.4 kgf, which is only 1.5-2 kg below typical harvest firmness and severely restricts the potential of conditioning to enhance flavour. Stop N Shop is less stringent, but still has been known to reject fruit that were 2.7-3.1 kgf on arrival at their shops, on the basis of being too soft. Generally packers in the Pacific Northwest do not condition pears below 4-4.5 kgf firmness immediately prior to trucking, and may leave them a little firmer if they are destined for distant, East Coast markets. Most return their conditioned pears to cold storage to chill them rapidly in order largely to prevent further softening prior to delivery. Some prefer not to return their pears to the cool store after conditioning at elevated temperatures, relying instead on the truck's refrigeration to return the fruit temperatures slowly to 0°C. In such cases, allowance must be made for further declines in firmness of 0.5-0.9 kgf to occur in transit.

USA protocols for ethylene conditioning

Treatment protocols must vary across the storage season in order to condition 'Green Anjou' pears optimally. Recently harvested 'Anjou' require ethylene conditioning for considerably longer than is necessary for fruit that have been stored until their chilling requirements have been satisfied (Chen 2002; Chen et al. 1996; Facteau & Mielke 1998; Villalobos-Acuna & Mitcham 2008). For 'Anjou' pears during the first 2-4 weeks of storage, a 4-day exposure to >100 ppm ethylene was found to be necessary to maximise the percentage of pears that subsequently ripened to acceptable eating quality (Facteau & Mielke 1998). Aroma production, in particular, was shown to be enhanced by prolonged ethylene exposures (6 days preferable to 3 days) during the first three weeks after harvest (Sharrock & Henzell 2005, 2007).

The current Pear Conditioning Guidelines issued by Pear Bureau Northwest (PBNW) (dated 1998) advise "For early season fruit, 72 hours of ethylene introduction may be necessary to achieve the desired firmness. For later season fruit, and fruit that has been stored for 2 or more months, 48 hours or even 24 hours may be sufficient." However, the Pear Handling Manual released in 2004 by PBNW suggests "For early season fruit, 48 hours of ethylene introduction may be necessary to achieve the desired firmness." The Pear Bureau is currently in the process of updating its conditioning guidelines, in light of recent research and consumer studies. Findings of a consumer preference study due to be released shortly by Kupferman and colleagues are likely to result in the recommended ethylene treatment periods being substantially increased.

Despite these research results and official guidelines, cost and logistical considerations are often over-riding factors for many packers. It is normal commercial practice early in the season in the Pacific Northwest to treat with ethylene for no more than 48 hours, following 24 hours of warming intended to make the fruit receptive. In the first month after harvest, such a conditioning treatment is definitely sub-optimal for triggering the capacity of ‘Anjou’ to develop its full aroma and flavour potential as it softens. A few packers have been more responsive to research findings and consumer feedback by employing conditioning protocols that change progressively during the storage season. Stadelman’s, a pioneer in establishing the “Ready-to-Eat” pear market, conditions early season ‘Anjou’ for up to 7 days, reducing to three days at around six weeks after harvest, and finally to two days at 16 weeks and beyond.

Skin defects

‘Green Anjou’ is a robust pear that transports very well, especially early in the season. However, scuffing can be a significant cosmetic problem if fruit are allowed to spin during trucking in loose-fitting tray cavities or over-sized clamshells. Shallow “Euro” packs and correctly fitting clamshells which grip but do not crush the fruit offer advantages over standard boxes of individually wrapped fruit by (i) allowing better air movement around the fruit, so it can be more efficiently warmed and cooled before and after conditioning, and (ii) protecting the fruit from pressure damage and stem punctures when they later ripen while on display. Sealed clamshells provide the ultimate protection and are the best way to avoid accumulating damage of soft ripe fruit from consumer handling while on display.

Scald typically becomes more of a concern later in the season, from February onwards. This physiological cosmetic skin defect normally becomes apparent once fruit fall below 4.5 kgf in firmness. Therefore, packers become more wary of conditioning fruit below this firmness from February onwards for fear that the sudden appearance of scald might downgrade their product before it is purchased. Fortunately conditioning is less vital at this stage, since by then ‘Anjou’ has gained the capacity to produce its own ethylene. However, there is still value to be gained from ethylene conditioning of ‘Anjou’ after its chilling requirement has been satisfied, through its continuing positive effects on flavour and aroma, and its coordination of softening. Besides this, several major chains in the USA now demand ethylene conditioning of ‘Anjou’ throughout the season.

Current status of the 'Ripe & Ready' brand, and its importance for growing the pear industry in Australia

'Ripe & Ready' is seen as an opportunity for growing the sales of 'Packham' pears through improving the eating experience of consumers. The importance of 'Ripe & Ready' is heightened given the limited opportunities for industry growth through canning and exports. However, inconsistencies in quality and ripeness of 'Ripe & Ready' in retail outlets to date have impeded the growth of this product line.

Perceived problems associated with supplying 'Ripe & Ready' pears

Many of the suppliers interviewed during this project stated they have substantially reduced their supply volumes of 'Ripe & Ready' pears in the last 1-2 years. Reasons for reduced volumes include:

- Lack of financial incentives to perform conditioning treatments when returns for conditioned pears are similar to those for non-conditioned pears, meaning that extra costs associated with ripening are not recouped
- Difficulties in achieving the firmness and appearance standards set by Coles for 'Perfectly Ripe' pears, and a perception the firmness standard of 2-4 kgf is too low for the pears to resist mechanical damage through the supply chain
- Lack of monitoring and enforcement of firmness standards set by Woolworths. Some suppliers only meet external specifications, as there is a belief that it is pointless trying to achieve a firmness standard that is not enforced
- Perception that conditioning treatments enhance skin yellowing, rots, shrivel and accentuate skin defects, resulting in higher rejections
- Loss of branding opportunities associated with the retail display packaging
- Concerns over the degree of pear movement in single and double layer trays that may result in increased mechanical damage
- Perception that 'Packham' are a commodity product, making it difficult to extract price premiums
- Difficulties in differentiation of 'Ripe & Ready' pears from non-conditioned pears in retail outlets by consumers and check-out staff
- Concerns over the mixing of trays of fruit in retail outlets with varying degrees of ripeness in display units
- Concerns that the brand name may be falsely raising consumers expectations, e.g. "Perfectly Ripe" suggests the pear should be ready to eat without further ripening at home.

Solutions to revive the 'Ripe & Ready' concept

Despite the problems associated with 'Ripe & Ready', many suppliers agreed it is a viable concept if solutions can be found for some of the problems above. During discussions with the pear suppliers it was evident that 'Ripe & Ready' lacks an industry champion. An industry champion/authority is needed to work alongside pear suppliers and supermarkets to ensure consumers have an opportunity to purchase pears with the sensory properties that result in repeated purchases. Currently pears are sold as 'Ripe & Ready', yet it is clear the intended quality and ripeness is not reaching the consumer, meaning the full potential of the brand has yet to be realised. The industry authority could refine standards for appearance and ripeness, and enforce these standards, to ensure the brand is protected. This would allow the industry to take more ownership over the supply process, rather than relying on the supermarkets to set and enforce standards for a product line they could just as easily replace with another type of fruit.

Pear suppliers also thought that the problem of variable ripening procedures between ripeners, and the recovery of extra costs associated with ripening, could be achieved by restricting the supply of 'Ripe & Ready' pears to licensed ripeners. These ripeners could undergo regular training and be monitored to ensure optimum conditioning procedures are followed. The question remains as to whether this licensing process should be run at the industry level, or if there is an opportunity for individual suppliers within the industry to drive the concept.

It was also apparent that one supplier had a very good relationship with the supermarkets and was able to plan one-two weeks in advance for supply volumes, and saw the benefit of being actively involved with in-market promotions. In contrast, other suppliers seemed to have a more distant relationship and seemed to have little warning of expected supply volumes. Having an open relationship is critical for delivering consistent high quality pears so that suppliers can schedule conditioning treatments to provide the correct ripeness at the correct time. The lack of communication between many pear suppliers and the supermarkets will be contributing the variability in ripeness on sale, as most suppliers may not have sufficient time to plan and implement the correct conditioning treatments. Ethylene conditioning of small orders on demand is typically not cost-effective, because of the need still to fill a large room with ethylene.

The packaging of 'Ripe & Ready' pears is another important aspect that needs to be addressed, following concerns over mechanical damage in transit. Conditioned pears are currently transported and displayed for retail using reusable display crates (RDC) (Figure 11). The position of pears within the crate is maintained using fibreboard trays, although this system is not sufficient to prevent pear movement in transit, potentially resulting in friction marks from fruit-to-fruit contact and/or from rubbing on the fibreboard tray. It is possible the perceived increase in damage by suppliers of 'Ripe & Ready' pears may not be associated with the conditioning treatments per se, but instead could be a consequence of the choice of packaging. Having conditioning facilities close to retail distribution centres may also offer advantages in reduced transit damage/ wastage

The current display tray system also limits branding opportunities to stickers on the fruit (Figure 11). However, it is questionable how effective the stickers are at differentiating 'Ripe & Ready' pears from other pears on retail display (see Figure 11 for retail display of several types of pears including 'Ripe & Ready'). The current labelling system also limits the ability to promote positive aspects of 'Ripe & Ready' pears (e.g. flavoursome and convenient), aspects that may attract consumers. Given that supermarkets are likely to insist on the continued use of RDCs, packaging options are probably limited to those that fit inside the RDC and replace the fibreboard tray. The use of recyclable plastic clam shells are an example of packaging that could fit this purpose (see Figure 12), in that fruit movement will be restricted to minimise friction damage, and also provide a larger surface for branding and promoting the product. Damage due to consumer handling can also be eliminated by the use of clam shells, which often incorporate a tamper-evident seal.

Figure 11. Display of ‘Ripe & Ready’ pears in reusable display crates (RDCs).

Figure 12. Example of recyclable plastic clam shells suited for packaging pears to minimise scuffing, pressure and consumer-handling damage and to provide a large surface for branding and promoting the product.

Conclusions

Following site visits to seven ripening facilities, it was evident that sub-optimal conditioning practices and inconsistencies between ripeners will be contributing to the variation in firmness of ‘Ripe & Ready’ pears sold in retail outlets. Significant improvements could be made to the uniformity of the product by implementing forced-air warming and cooling before and after conditioning treatments. Improvements in quality and flavour could also be achieved through optimising the conditioning temperature and ethylene dosage (i.e. concentration and length of exposure). The current procedures used by ripening facilities are unlikely to be delivering the ripeness, and consistency of ripeness, required to grow the ‘Ripe & Ready’ brand through increased consumer demand and satisfaction.

The biggest opportunity for ‘Ripe & Ready’ is to maintain pear sales early in the season through providing ripe, aromatic ‘Packham’ that follow on from ‘William bon Chrétien/Bartlett’. This opportunity could be realised through the implementation of new ethylene-based ripening protocols, improved packaging both to protect and to discriminate conditioned fruit, and also through implementing procedures to protect the brand by ensuring that ripeness standards are consistently achieved. This would allow the industry to take more ownership over the supply process, rather than relying on the supermarkets to set and enforce standards for a product line they could just as easily replace with something else.

Recommendations

Short term

- Implementation of forced-air warming systems before conditioning, and forced-air cooling following conditioning, to produce a more even ripening response
- Improved procedures for monitoring firmness during conditioning
- Establish workgroups and workshops for ripeners and retail representatives to improve procedures for ripening, monitoring quality, inventory management, handling during transport, retail presentation and waste management
- Devising industry strategies for enforcing standards and protecting the reputation of the 'Ripe & Ready' brand, e.g. being licensed to supply 'Ripe & Ready pears
- Research to produce the knowledge essential for developing a robust ripening protocol for 'Packham'. The current protocol is largely based on knowledge from responses in other cultivars (for which there is plenty of information), cultivars which may have different ripening characteristics. Knowledge deficiencies for 'Packham' include establishing benefits of ethylene conditioning, optimising harvest maturity, optimising the conditioning temperature to reduce wastage, investigating potential benefits from packaging alternatives currently available, and establishing tolerance levels of consumers to external defects.

Medium to long term

- Development and implementation of a more robust ripening protocol for 'Packham' according to experimental and commercial-scale trials optimising conditioning temperature and ethylene dosage, and harvest maturity.
- Ongoing training and up-skilling of ripening personnel facilitated through workshops
- Development of packaging solutions to:
  - Minimise pear movement and friction damage in transit
  - Differentiate conditioned pears from non-conditioned pears in retail display units
  - Improve the branding and promotion of 'Ripe & Ready' pears. Currently the branding and promotion opportunities are restricted to small fruit stickers.
- Development of orchard strategies for increasing pack-out percentages based on standards that reflect consumer expectations for external appearance.

For further information, please contact:

Dr Jason Johnston
Plant & Food Research, Auckland
Private Bag 92169, Auckland Mail Centre
Auckland 1142 New Zealand
Email JJohnston@hortresearch.co.nz
Tel +64 9 925 7247; Fax: +64 9 925 7001

References

Apple and Pear Australia Ltd. 2007a Pears domestic marketing program 2007. http://www.apal.org.au/assets/static/2007-Pears-Marketing-Program.pdf.

Apple and Pear Australia Ltd. 2007b Guidelines for postharvest drenching of apples and pears. http://www.apal.org.au/.California Pear Advisory Board 2004. California Bartlett: ripening and handling. www.calpear.com/pub_documents/CPAB_ripening_manual_04.pdf.

Chen PM 2002. Pre-conditioning 'd'Anjou' pears in transit during early marketing season. Washington State University Tree Fruit Research and Extension Center, Postharvest Information Network. http://postharvest.tfrec.wsu.edu/REP2002A.pdf.

Chen PM, Drake SR, Varga DM, Puig L 1996. Preconditioning of 'D'Anjou' pears for early marketing by ethylene treatment. Journal of Food Quality 19: 375-390.

Dignam M 2000. AHC/NIAA Consumer and technical fruit quality study. Report for The Australian Horticultural Corporation in conjunction with The Australian Apple and Pear Growers Association.

Facteau TJ, Mielke EA 1998. Effect of harvest maturity and postharvest-prestorage ethylene treatment on the storage and ripenability of d'Anjou pears. Acta Horticulturae 475: 567–574.

Hansen E, Mellenthin WM 1979. Commercial handling and storage practices for winter pears. Oregon State University Agricultural Experiment Station Special Report 550.

Maxie EC, Parsons RA, Mitchell FG, Mayer G, Snyder RG 1974. Effect of rates of poststorage warming on ripening of 'Bartlett' pears, *Pyrus communis* L. Journal of the American Society for Horticultural Science 99: 408-411.

Pear Bureau Northwest 2004. Pear handling manual. www.usapears.com/trade

Poelman A, Forde C. 2006. Evaluating consumer responses for pre-ripened Packham pears. FoodScience Australia, September 2006 (HAL project AP06046).

Poelman A, Gray S 2007. Ripe pears are preferred, but will consumers pay? Australian Fruitgrower, April: 7.

Sharrock KR, Henzell RF 2005. Ethylene ripening of pears by unconventional means. Northwest Pear Research Review, February 2005 pp. 84-90

Sharrock KR, Henzell RF 2007. Ethylene ripening of pears by unconventional means. Northwest Pear Research Review, February 2007: http://jenny.tfrec.wsu.edu/wtfrc/PDFfinalReports/2007FinalReports/Sharrock.pdf

Villalobos-Acuna M, Mitcham EJ 2008. Ripening of European pears: the chilling dilemma. Postharvest Biology and Technology 49: 187-200.

Watkins CB, Bartsch JA 1997. Calibration and use of penetrometers, refractometers, gas monitoring equipment, and thermometers. Washington State University Tree Fruit Postharvest Journal 8: 6-10.

Acknowledgements

We thank the pear suppliers for their enthusiastic and helpful input into this project, and for allowing us to access and critique their ripening facilities. We look forward to working with these supply groups in the future.

Appendix A – Procedures for individual ripening facilities

Ripening facility A

Visit date – 29 September 2008

1. Fruit stored in wooden bins in CA (1.8% O_2, 2% CO_2) at 0-0.5°C. Plastic tops/covers used on bins to reduce water loss / stem-end shrivel. CA applied 3-4 days after harvest. Fruit drenched with DPA before CA storage for scald control.
2. From June onwards, remove fruit from CA, grade, pack (single layer 85 mm or double layer 120 mm), stack in pallets (6 columns x 6 single layer trays high). Use both single (85 mm) and double (120 mm; 8 kg) layer trays, prefer single layer tray for ripening.
3. Leave pallets to warm/sweat at ambient temperature in packing shed overnight, and then place pallets into a ripening room (50 to 100-pallet capacity) set at 18-20°C, 80% RH. Fruit probed to check flesh temperature. Fruit temperature once left the packing line is approx. 8°C.
4. Fruit held in ripening room until firmness decreases by 1 kgf; generally this takes 24-48 hours. Fruit warming in ripening room is achieved using standard evaporator fans, forced-air warming system not used.
5. After ripening, the fruit are checked for defects (top tray only for double layer trays) and returned to a coolstore with standard evaporator fans to cool to 3°C before transport. Forced-air cooling used sometimes.
6. Metal shelving system used for inventory management and stock rotation of ripened pears.
7. Temperature specification for transport is 4-7°C. There is a perception that temperature may increase by 2-5°C during transportation. Pallets not shrink-wrapped during transport.
8. A separate temperature (20°C) and RH (80%) controlled room is used for library samples (approx. 30 fruit per grower batch) to monitor ripening rate and shelf life. Fruit assessed for firmness (drill press-mounted Effegi), soluble solids (eye-piece refractometer), skin colour, disorders and rots. Sinclair has been used in the past.
9. Ethylene not monitored in CA rooms, air coolstores, ripening room, or library sample room.

Ripening facility B

Visit date – 30 September 2008

1. Air storage for 1 month (late maturity fruit), CA storage until November (optimal maturity fruit). CA conditions = 3% O_2, 2.5% CO_2, temperature 0-0.5°C. Storage in wooden bins with a plastic sheet stapled over the top of each bin. Fruit dipped in DPA on the day of harvest or next morning for scald control.
2. Fruit are removed from storage, packed in trays while cold, palletised (72 trays per pallet), left to warm/sweat at packing shed ambient temperature, and then transferred to a dedicated ripening room at 24°C, 80% RH. Ripe N Ready pears are not packaged in liners, while the non-ripening equivalents are wrapped.
3. The ripening room has a forced-air system with 3 stations. A maximum of 9 pallets in the ripening room at any one time, arranged in 3 rows of 3 pallets. Each row of pallets are then independently forced-air warmed. This is achieved by each row having its own fan, covering the sides and top of the row, and air drawn from the end through each pallet (pallets cooled in series rather than in parallel).
4. Fruit are maintained in the ripening room for 2-3 days. A library crate is also held in the ripening room to monitor progress. Firmness is monitored using a hand-held Effegi penetrometer and soluble solids with an eyepiece refractometer. Sinclair was used 2 years ago to reduce waste, but reverted to destructive testing as wastage wasn't unacceptably high.
5. Ethylene ripening used to be performed, but reverted to temperature ripening only as cost of ethylene gas considered too high and thought that the fruit quality benefits weren't strong enough (e.g. did own trial and found that variability was only slightly less after ethylene treatment). The benefits of ethylene for ripening early season pears have not been investigated by this ripener. The operator has no control over dosage concentration or shot intervals. The system was setup by Humifresh.
6. The ripened fruit are then checked for defects, labelled (machine - 4 lanes, one pass), and cooled to 0°C in a room with standard evaporator fans and high air flow (not forced-air cooled). Coles specify that the fruit need to be cooled to 2°C before transport.
7. It is thought that the fruit temperature can increase to 6-7°C during transportation.
8. The ripening room is cleaned yearly to remove mould spores etc. This included removing the forced-air system.

Ripening facility C

Visit date – 30 September 2008

1. Fruit packed and sold in May and June are air-stored, while those packed and sold later in the season are stored in CA (July – December). Fruit dipped in DPA within hours of arriving in the packing shed.
2. Fruit are stored in bins, then packed while cold, palletised and either left overnight at room temperature in the packing shed to warm/sweat, and if not sufficiently advanced be transferred to a dedicated ripening room (25-26°C, high RH) for 2-3 days. Ripe N Ready fruit are not packed in liners, while the non-ripened fruit are hand-wrapped in paper to prevent marking.
3. The ripening room is equipped with a humidifier and an air conditioning unit in the ceiling, with little airflow, and can accommodate 50-60 pallets.
4. Fruit are ripened to 4-6 kgf. This is monitored by measuring firmness (Effegi penetrometer) and soluble solids (eyepiece refractometer) on a 12 to 13-fruit library sample held in plastic bag (holes) on a shelf in the packhouse (i.e. no temperature control) directly outside the ripening room.
5. Following ripening treatment, the fruit are then passively cooled to 0°C in a moderate to high airflow racked room (but not forced-air cooled) until required for refrigerated transport.
6. Fruit are sprayed with Rovral® during packing to reduce postharvest rots.

Ripening facility E

Visit date – 1 October 2008

1. All fruit stored in wooden bins with plastic lids in CA (1.5% O_2, 2-3% CO_2) at 0°C. Fruit are dipped in DPA before storage for scald control.
2. The fruit are packed into double layer trays as required during the season, and then transferred to a dedicated ripening room set at 24-25°C. The fruit are drenched in DPA (scald control) and Rovral (rot control) and packed while cold, and then passively warmed in the ripening room using an evaporator fan and a heater.
3. The pallets of freshly packed fruit are consolidated during the day in the ripening room. The ripening (ethylene and temperature) treatment is not initiated until the end of the day.
4. Ripening treatments are for 36 to 48 hours early in the season (June/July), and for 24 hours later in the season. Ripening treatments cease in December because of the high risk of rots and shrivel.
5. One library tray of fruit is monitored during ripening treatment, with the library sample positioned inside the ripening room.
6. Automatic ethylene treatment system is used all year round. This system uses RipeGas® (6% ethylene in CO_2), with the system set at 24 ppm. The system is serviced annually.
7. Humidifier used in the past, not sure if it is still used.
8. Following ripening treatment, the fruit are cooled in the same room (by turning on the coolant), no forced-air cooling. Aim is for 1-2°C, as the transport target is a set temperature of 2°C.

Ripening facility F

Visit date – 1 October 2008

1. Fruit stored in bins in CA at 0°C.
2. Fruit transferred from another facility (warm to 1-2°C during transfer), held in cold room at 0°C until packing.
3. Fruit packed while cold into single layer trays (i.e. not warmed before packing), palletised, and left to warm/sweat over the day before transfer to a dedicated ripening room.
4. Ripening room running at 22-24°C, and humidified. Ripening room contains a forced-air system suitable for warming 2 independent rows of pears. Cardboard is placed at the end and over top of pellet row, forcing the air to move in from the sides. Fruit temperatures are checked in ripening room using core probes.
5. Automatic ethylene release system with RipeGas (45 g/kg) used, set at 15 ppm (was reduced to 12 ppm according to instructions from Coles). Ripening treatment duration of 72 hours for early-season pears (June/July), and 24-36 hours for longer stored pears (lower ripening resistance).
6. Firmness monitored during ripening by sampling 3 fruit on 3 occasions using an Effegi penetrometer. Aim is to achieve a firmness of 4.0 to 5.0 kgf.
7. After ripening treatment, the fruit are checked, stickered, and passively cooled in a room with standard evaporators.
8. Cooled to 2°C before refrigerated transport.

Ripening facility G

Visit date – 2 October 2008.

1. Fruit arrive in refrigerated trucks, at a temperature of 2-3°C. The fruit are left on the dock for up to half a day before transfer into the cold room or the ripening room. During this time the fruit temperature can increase to 5-15°C.
2. Fruit arrive in single layer and double layer trays (RPCs with fibreboard).
3. Before ripening treatment, the fruit are held at ambient temperatures overnight to warm/sweat the fruit, and then transferred to a dedicated ripening room.
4. Ripening room is set at 18-19^{o}C. The fruit pulp temperature is also checked. The ripening room is equipped with a forced-air system. This system is equipped with one fan and a Thermofresh® water cooling system to maintain high humidity. The room is loaded to give 2 rows of pallets (2 pallets high, 11 single trays high per pallet), which are then covered with a tarpaulin that covers the top and ends of both rows. This forces the air through the sides of the pallets into the central void between the rows of pellets.
5. Ripening room is also equipped with a Humifresh ethylene pulse delivery system. The system also monitors CO_2, with a maximum CO_2 setting of 0.8%. The operator has no control over the ethylene concentration delivered; this is set up and maintained by Humifresh.
6. Firmness is monitored by feel and on one fruit per day during ripening with an Effegi penetrometer. Aim is to achieve a firmness of 2.7-3.6 kgf (6-8 pounds). Ripening treatments can take 4-5 days for early-season fruit (May-June), and 2-3 days for later-season fruit.
7. Following ripening treatment, the fruit are re-graded and stickered, and then passively cooled using standard evaporator fans to 1-2°C before refrigerated transport.

Appendix B – GT automatic fruit ripener

GT Automatic Fruit Ripener

GT Automatic Fruit Ripener

designed and made in Australia

- for automatic control of ethylene in ripening and degreening rooms

The GT Automatic Fruit Ripener has been recently developed and tested in Australia to automatically control the concentration of ethylene in rooms used for fruit ripening or degreening using the latest in gas sensing technology. The unit has a permanent solid-state detector which constantly measures the ethylene and electronically operates a gas solenoid to keep a low concentration to within one part per million. While the unit was designed to maintain constant concentrations up to 200ppm, in the field tests it has been found that just a constant 10ppm is suitable for any fruit ripening or degreening concentration. In over four years of tests the units have been found to be extremely consistent and reliable.

- ✓ Newly developed and tested
- ✓ Suits all fruit ripening and degreening
- ✓ Automatically controls ethylene concentration
- ✓ Independent of room size or free space
- ✓ Continuous digital display of room ppm
- ✓ Re-equilibrates after door openings
- ✓ Simple and easy to install – DIY
- ✓ Plugs into normal power outlet
- ✓ Better fruit quality, more uniform ripening
- ✓ More consistent fruit quality, week to week
- ✓ Maintains any low concentration
- ✓ Constant to within 1 part per million
- ✓ Greatly reduce ripening gas usage
- ✓ Increases safety of using ethylene
- ✓ Simple and easy to install
- ✓ Can eliminate the need for safety equipment
- ✓ Can connect to computer control
- ✓ Permanent detector never needs replacing
- ✓ Optional auto-dialer as safety monitor
- ✓ Technical backup and advice readily available

The uniform and consistent ethylene concentrations means that fruit quality is improved. Recent DPI trials have shown that 10ppm ethylene produced better quality mangoes than 100ppm or higher. For citrus degreening, low concentrations of ethylene are used to prevent citrus-burn.

The beneficial consequences of this consistency and reliability to maintain a 10ppm concentration or lower are only just being recognised. It means that gas costs are so minimal that it now becomes economic to use the non-explosive Ripegas® which provides absolute zero risk of explosion and avoids the additional capital costs and maintenance of expensive safety equipment and insurance premiums.

Additionally, the GT Ripener offers many other advantages:

- Much simpler and better than existing systems - fully automatic, turn it on and it automatically maintains any set concentration in any sized room.
- Maintains a set concentration irrespective of ripening room doors being opened, volume of free space in the room, or the ventilation rate. The unit simply admits more gas as required and shuts off when a set concentration is reached.
- Can maintain even very low concentrations of gas typically 5 or 10ppm. Higher concentrations up to 200ppm can be set, but 10ppm has been found to adequate for every operation tested so far.
- The solid state detector is permanent, does not need replacing after a fixed period