Final Report

Supply Chain Quality Improvement – Cool Chain Best Practice Guidelines

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Delivery partner:

Applied Horticultural Research

Project code:

AV15010

Project:

Supply Chain Quality Improvement – Cool Chain Best Practice Guidelines – AV15010

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Summary

The supply chain studies clearly showed that adopting best practice results in a significant reduction in the level of damaged fruit at retail. Optimum supply chain practice resulted in less than 10% of fruit damaged measured at retail, moderate levels of adoption of best practice resulted in 10-15% of the fruit at retail damaged, and poor practices led to more than 20% of fruit at retail damaged.

To support improvements in best practice, the project has developed a suite of Best Practice Resources for supply chain management by the Australian avocado industry. The project began by conducting a comprehensive review of international and local research on management of avocado quality. This included pre-harvest and postharvest effects on quality from the time of planting through production, harvest, packing, ripening and display at wholesale. In addition, existing best practice resources were reviewed to determine gaps and opportunities for improvement.

At the same time, a series of industry consultations were initiated to understand how avocados are managed in Australia. The outcome of the consultations suggested that participatory research relating to the project should focus on key packhouses in different regions central to, growing and marketing of avocadoes.

A series of studies were therefore conducted in 12 packhouses in five growing regions. These examined impacts during harvest, sources of postharvest damage and temperatures in supply chains from farm to retail. Key findings (summarised in Attachment 1) include:

- Significant impacts can potentially occur when harvesting from mechanical work platforms if the bag is left at full extension; restricting the bag around the middle and releasing fruit gradually should prevent damage
- Most impacts on packing lines were below damage thresholds, however, it was found that overloading fruit on the line and excessive brushing increased lenticel damage on Hass fruit
- Room cooling of bins of avocados is relatively slow, with large differences between the centre and outside of the bin; these can be eliminated using forced-air cooling
- Fruit pulp temperature at dispatch was above 6°C in 11 of 13 supply chains monitored, and above 10°C in four supply chains
- Only one of the 13 supply chains monitored maintained fruit temperature at 5°C during transport. The majority averaged 8 to 12°C with significant variation occurring; in many cases fruit temperature rose during transport, suggesting that truck cooling systems were inadequate to cope with heat generated by the avocado fruit
- Ripening temperatures were variable, with the best results gained when ripening rooms were equipped with forced-air systems for heating as well as cooling fruit
- Most packhouses did not meet all best practice guidelines – five of the 12 packhouses had issues that would be expected to impact fruit quality.

The results of these studies, together with outcomes from the reviews, direct input from other researchers and industry feedback were used to develop a series of four best practice resources – the Australian Avocado Supply Chain Best Practice Guide, Problem Solver, Checklists and a Ripeness poster.

The best practice materials have been printed, distributed and supported by a series of 7 workshops conducted jointly with Avocados Australia Limited (AAL) around Australia, and with a total attendance of at least 426 growers, packers and industry members. The resources are also available through the Avocados Australia BPR and have been promoted using emails and newsletters. In addition, multiple copies of the best practice materials have been requested from major packhouses and the retail sector.

This approach has been well received by industry, with positive feedback on the information and resources produced. Several packhouses have already implemented changes in their procedures as a result of the specific studies on their own supply chains. Others have expressed strong interest in the guidelines and an intention to move towards these practices in the future. The conclusion is that a participatory approach to research with industry is an excellent method for encouraging practice change and adoption of best practice within supply chains but that further efforts are required to implement the supply chain improvements broadly across the industry, especially with a focus on effective cool chain management.

Keywords

Avocado; supply chain; cool chain; best practice; postharvest; temperature; fruit quality; bruising; impact; lenticel

Introduction

Surveys of avocados at retail over several years have consistently found that 20–25% of the fruit on sale has significant damage. This is defined as >10% of the internal flesh having bruising, internal rots, or other disorders. The total GVP of avocados in 2015 was $412.3 million, so in simple terms, 25% damage means that retailers are paying about $100 million per year for damaged fruit, and presumably consumers spend about $150 million per year on such inferior fruit. This reduces consumer satisfaction (Gamble et al., 2010) and limits potential expansion of the sector.

Australian avocado production is expanding rapidly, with a large percentage of trees in the ground less than three years old. To maintain profitable returns to growers, the demand for avocados needs to increase. Given the known issues with damaged fruit, quality improvement is an obvious way to increase consumer demand. Hort Innovation therefore developed three projects as part of a Supply Chain Quality Improvement Program:

1. Technologies and practices to reduce bruising (AV15009)
2. Cool chain best practice adoption (AV15010)
3. Retailer point-of-purchase improvements (AV15011).

Cool chain and handling practices from harvest to retail have a major impact on levels of bruising, rots and other internal quality defects, therefore the objectives of this project were:

- To increase the adoption of best practice in cool chain management and postharvest handling across all sectors of Australian avocado supply chains – from orchard to retail
- To reduce the incidence of body rots and other quality defects in avocado fruit
- To increase the awareness across the supply chain of factors that predispose fruit to quality defects

Methodology

Summary

The initial phase of the project involved reviewing postharvest avocado research and existing best-practice resources. At the same time, industry consultation and supply chain studies at major avocado packhouse were conducted to identify key issues in the supply chain that impact on fruit quality and ensure that new recommendations were commercially viable.

Review findings: new data and input from stakeholders across the supply chain were combined to produce four new supply chain best-practice resources. A final extension phase of the project involved re-engaging with the major packhouses, and presenting the new resources and recommendations at workshops across all major avocado growing regions.

Summary of project methodology.

Reviews

Pre- and postharvest management of avocados: A review of best practice

Avocados have been extensively researched both, internationally and here in Australia. An initial literature search revealed 8,750 peer-reviewed papers relating to pre- and postharvest management of avocado fruit. This review sought to summarise key research findings that could be used to improve management of avocado quality. More than 200 papers were included in this document, which represents an extensive review of the many factors that impact on fruit quality through the supply chain.

Topics covered include: pre-harvest effects on postharvest quality; harvest; pre-cooling; postharvest treatments and packing; cooling and storage; ripening. Each section of the review identifies practices that can best maintain fruit quality, and other quality issues that may arise from less-than-optimal practices. Key gaps in existing knowledge were noted, and recommendations for further work are included as future R&D opportunities.

The document has been well received and forms much of the basis of subsequent best-practice recommendations (Publication – provided separately).

Review of existing best practice materials

A second review (Appendix 2) was undertaken of all current Australian avocado supply-chain materials (orchard through to retail) in September 2016. That included printed materials and the Avocados Australia online Best Practice Resource. Content and ease of use, e.g. organisation of information, format and presentation) was evaluated for each resource to identify areas of improvement.

Recommendations for improvements of the online best-practice resource (BPR) were provided to Avocados Australia, while gaps in existing content or resources were identified for development of new resources later in the project. Many of these recommendations have already been implemented, with the new site recently launched around Australia.

International supply-chain education materials from industries including avocado, mango, banana, pear and grapes were also studied for useful ways of presenting material.

Finally, existing Australian best-practice recommendations at each stage of the supply chain were compared with best-practice recommendations in New Zealand, South Africa the US and those identified from the review of research. Gaps or differences in Australian recommendations were identified and considered later in the project during the production of new resources.

Review of current and potential developments in chemistry and practices for managing avocado postharvest disease

Chemistry and practices for managing avocado postharvest disease were reviewed by plant pathologist Dr Len Tesoriero. That included the pathogens involved, contributing factors for pre- and postharvest infection, as well as current and potential control options pre- and post-harvest. Details from that review were then incorporated into the new best-practice resources and recommendations were provided for future work (Appendix 4).

Audit of supply chain practices and packhouse extension studies

Initial audit of practices

Initial discussions were held with members of each supply-chain group to assess their practices and understand barriers to adoption. Supply-chain participants and the PRG were consulted about best-practice recommendations that were identified from the review of research and whether they were commercially feasible. Meetings were held with a number of stakeholders across the supply chain:

- Growers – 4
- Packhouse managers – 6
- Ripener/wholesalers – 3
- Retail product technologists/avocado category managers – 8, including Coles, Woolworths, Aldi, Costco, Metcash/IGA

These initial meetings helped identify some of the key issues to be addressed in the new best practice resources and extension program (confidential reports provided directly to co-operators).

Packhouse supply chain studies

Discussions with supply-chain stakeholders and the PRG led to the decision to focus the extension phase of the project on 10–15 major avocado packhouses. Packhouses have influence both forward and back along the supply chain, extending from growers to ripeners and even retail. Targeting major packhouses in each growing region would be the best way to achieve a more efficient and widespread extension program.

All avocado packhouses were provided the opportunity to participate, with an invitation provided in the Avocados Australia *Guacamole* newsletter and *Talking Avocado*s magazine. In addition, the largest 12 avocado packhouses in Australia were individually contacted and invited to participate. In total 12 packhouses participated across five states:

Region	Number of packhouses	Date (2017)
North Qld	3	May
Central Qld	3	July to August
Central NSW Coast	2	September
Riverland SA	1	October
Southwest WA	3	November

The packhouse studies covered key practices from harvest to retail store, focusing on temperature management. A confidential report of findings and recommendations was provided to each packhouse on completion of the study, and a follow-up discussion was held with them during the regional extension workshops later in the project.

Practices and issues assessed included:

Fruit handling and impacts

Recording harvest impacts.

- Harvest impacts
- Bin compression damage
- Packing line impacts
- Lenticel damage along the packing line

Temperature management

- Harvest to packing
- Cooling after packing
- Transport
- Ripening
- Ripener to retail

Fruit quality assessments through the supply chain

Probe temperature logger.

A more detailed methodology is available in the Packhouse studies report (Appendix 1).

Revision and development of best practice resources

Four new best-practice resources were developed based on needs identified from initial industry and PRG consultation, including:

- Australian Supply Chain Best Practice Guide
- Avocado Fruit Quality Problem Solver
- Australian Avocado Supply Chain Checklists

- Stages of ripeness chart

The reviews from earlier stages of the project were used to update best-practice recommendations where necessary. Some of the data collected in the packhouse supply-chain studies was also incorporated into the new materials.

QDAF were subcontracted to review their existing HACCP analysis document. That was then provided to the project team, and incorporated into the Supply Chain Checklists.

Final drafts of all four resources were reviewed by avocado experts from QDAF, PRG members and other growers, packers, ripeners and retailers. Input was also provided from the AV15009 and AV15011 project teams.

Resources were printed (1000 copies each), as well as added electronically to the Avocados Australia Online Best Practice Resource.

Final extension and implementation program

New best-practice resources were distributed to avocado supply-chain stakeholders at regional workshops and as requested after the resources were promoted in *Guacamole* and *Talking Avocados*.

Information on the project's key findings, as well as the recommendations made in the new best practice resources, was presented to supply-chain stakeholders in all major grower regions through a series of regional meetings (see outputs).

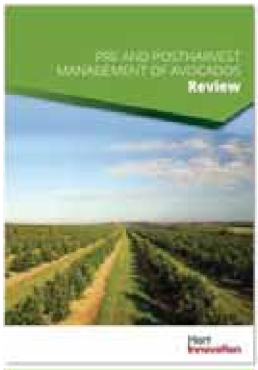
Alongside those meetings, follow-up discussions were held with the packhouses involved in the supply chain studies. Recommendations were revisited, and progress towards implementation of change was discussed.

The new project resources will also be on display at Hort Connections in Brisbane, June 2018. The project team will also be available at the booth for discussions with avocado industry stakeholders.

Outputs

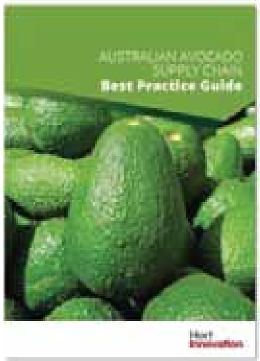
Publications

Review of pre and postharvest management of avocados



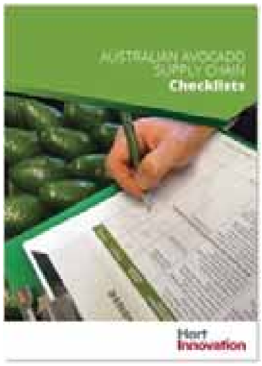
This document provides a detailed review of international avocado research. In particular, factors that affect postharvest quality of avocados are reviewed.

Australian Avocado Supply Chain Best Practice Guide



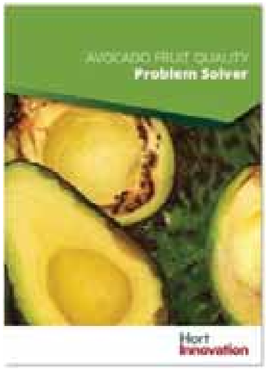
This guide summarises best-practice recommendations from grower to transporter to retailer. It includes guidelines on how the key factors affecting avocado quality can be managed to supply consistently high-quality fruit. It also demonstrates (at each stage of the supply chain) how losses in quality can occur if best practice is not followed. The guide has a strong focus on temperature management, which is one of the most critical factors in maintaining postharvest quality.

Australian Avocado Supply Chain Checklists



The checklists summarise the key actions needed to maintain the postharvest quality of avocados. A number of records are suggested, as a way of ensuring activities are correctly performed and recorded. Space is left for the business to determine which processes have the highest priority and the status of each activity can be noted by the relevant staff. The checklists should be reviewed regularly to allow system improvements from month to month and season to season.

Avocado Fruit Quality Problem Solver



Designed to be used in conjunction with the best practice guide, it outlines the major fruit quality issues that can occur as avocados travel through the supply chain. The focus is on postharvest issues and includes external and internal defects as well as ripening- and storage-related problems. The problem solver can be used to help you identify a problem, find out what is causing it and how to minimise or prevent it.

Stages of Ripeness Chart

This chart is aimed at ripeners, wholesalers and retailers, and outlines the five stages of avocado ripeness. The chart provides descriptions of each stage and management/use of fruit at each stage.

Reports

Review of avocado best practice resources – Australian and international

This document reviewed all Australian and international avocado supply-chain best-practice resources, according to content, recommended practices, and ease of use. Recommendations from the review were used in the development of the new best-practice resources produced in this project, as well as updates that Avocados Australia made to the online Best Practice Resource (Appendix 2).

Research gaps summary

A brief report on research gaps identified from the review of pre and postharvest management of avocados (Appendix 3).

Disease control review

This review examines current knowledge of postharvest disease management issues and control measures in the avocado industry (Appendix 4).

Mission Produce visit

A brief report on a visit to the Mission Produce facility in Oxnard, California. Key supply-chain practices that Mission Produce follow are detailed (Appendix 5).

Packhouse and supply-chain study reports to 12 packhouses

These confidential reports were provided to packhouses after their packhouse and supply-chain study. They include key supply-chain issues and recommendations for change.

A non-confidential summary report on all 12 studies is provided as Appendix 1.

Presentations / workshops

- Grower/packer presentations
  - Atherton avocado grower meeting, 3 May 2017, 10 attendees (Appendix 6)
  - Bundaberg avocado study workshop, 17 August 2017, 81 attendees (Appendix 7)
  - Regional meetings (Appendix 8)
    - Crows Nest, Qld – 1 May 2018 64 attendees
    - Sunshine Coast, Qld – 2 May 2018 49 attendees
    - Bunbury, WA – 15 May 2018 83 attendees
    - Renmark, SA – 21 May 2018 42 attendees
    - Mareeba, Qld – 31 May 2018 73 estimated attendees
    - Stuarts Point, NSW – 5 June 2018 53 estimated attendees
    - Childers, Qld – 7 June 2018 62 estimated attendees
- Project reference group
  - 13 February 2017 (Appendix 9)
  - 14 August 2017 (Appendix 10)
  - 14 March 2018 (Appendix 11)
- Retailers
  - Coles – avocado category manager and product technologist – 10 May 2017
  - Woolworths avocado category manager – 20 March 2017
  - Aldi – produce QA – 30 March 2017
  - Costco – Assistant produce buyers – 23 March 2017
  - Metcash – National avocado category manager – produce – 23 March 2017
- Other
  - R&D forum in Brisbane – 8 November 2017 (Appendix 13)

- Sydney University Institute of Agriculture – 27 March 2018 (Appendix 14)

Articles

Talking Avocados (Appendix 15)

- Winter 2017 – 'Avocado supply chain improvement projects are well underway'
- Summer 2018 – 'Avocado cool chain best practice adoption'
- Autumn 2018 – 'New avocado supply chain resources'

Monitoring and evaluation

Monitoring, Evaluation, Reporting and Improvement (MERI) plan (Appendix 16).

Outcomes

Improvements in fruit quality

The supply chain studies clearly showed that adopting best practice results in a significant reduction in the level of damaged fruit at retail. Best cool chain practice resulted in less than 10% of fruit damaged at retail, moderate levels of adoption of best practice resulted in 10-15% of the fruit at retail damaged, and poor practices led to more than 20% of fruit at retail damaged (Table 1 and Appendix 1).

Table 1. Summary of packhouse and supply-chain practices, and resulting internal fruit quality from studies across 12 Australian packhouse supply chains.

Key: Consistent with best practice; Improvements required; Issue needs urgent improvement

Packhouse	Supply chain length*	Harvest impacts	Impacts along packing line	Cooling before packing	Cooling after packing	Transport temperatures	Ripening temperatures	Ripener to retail temps	Internal damage at ripe
1	Long			No, but pick to pack < 24hrs	9°C within 20 hrs	Avg: 10°C Min: 7°C Max: 11°C			
2	Long				10°C within 24 hrs	Avg: 8°C Min: 5°C Max: 11°C			
3	Long			No, but packing within 24hrs	None, loaded @ 16°C	Avg: 11°C Min: 9°C Max: 12°C			
4	Medium			Room cooling to 10°C within 15 hrs	8°C within 16hrs	Avg: 9°C Min: 8°C Max: 12°C	Forced-air warming to 18°C, then down to 5°C	4-8°C at retail DC and in to store	Low at ripener and retail
5	Medium		Skin damage from brushes	Room-cooled to 8°C but rewarmed to ambient at packing	None, loaded at 20°C	Avg: 12°C Min: 9°C Max: 20°C	No forced-air, slow warming, then 15-20°C	7-9°C for 12 hrs	High levels at points after transport

Packhouse	Supply chain length*	Harvest impacts	Impacts along packing line	Cooling before packing	Cooling after packing	Transport temperatures	Ripening temperatures	Ripener to retail temps		Internal damage at ripe
6	**Medium**		No damaging impacts	Room-cooled from 30 to 21°C, but packed within 24hrs	10°C within 20hrs	Avg: 9°C Min: 7°C Max: 11°C	Slowly increased to 20°C, then forced-air to 5°C	Load 1: 8°C for 24hrs Load 2: 5-10°C for 48hrs		Low-medium levels (10-15%) at all stages
7	Short		No damaging impacts	Forced-air from 27°C to 10°C in 10 hrs	Cooled to 7°C before dispatch	Avg: 9°C Min: 5°C Max: 12°C	Forced-air warming to 18-20°C, then forced-air cooling to 5°C			Low levels of at all stages of supply chain
8	Short and medium		Damaging impacts, flesh bruising identified		Room-cooled to 7°C within 30 hrs	Short length: Avg: 6°C Min: 5°C Max: 8°C Medium length Avg: 12°C Min: 8°C Max: 15°C	Forced-air warming to 15-20°C, then forced-air cooling to 5°C			Moderate incidence (15%) of rots at all stages of supply chain
9	Medium		Bin tip impacts close to damaging level	Held at 20°C and packed within 24 hrs	5°C within 20 hrs	Avg: 8°C Min: 5°C Max: 12°C	Forced-air warming to 15°C-20°C, forced-air cooled to 4°C			High incidence (30-50%) of low level rots at all stages

Packhouse	Supply chain length*	Harvest impacts	Impacts along packing line	Cooling before packing	Cooling after packing	Transport temperatures	Ripening temperatures	Ripener to retail temps	Internal damage at ripe
10	Long	Damaging impacts in cherry picker bags	No damaging impacts	Room-cooled 23°C to 15°C within 20 hrs	12°C at dispatch	Load 1: **Avg**: 10°C Min: 7°C Max: 12°C Load 2: **Avg**: 12°C Min: 7°C Max: 15°C			High incidence (50-100%) of severe rots (>20% flesh affected)
11	Long	Damaging impacts in cherry picker bags	No damaging impacts	Room-cooled from 25°C to 10°C within 25hrs.					
12	Long		No damaging impacts		Forced-air cooled to 5°C	**Avg**: 5°C Min: 4.5°C Max: 6°C			

*Supply chain length - Long: >2000km, medium: 1000-2000km , short: <1000km

Key supply chain issues identified

In addition, key issues in avocado supply chains have been identified (Appendix 1). Of these, temperature management is a major concern, particularly during transport. Data collected during the project clearly demonstrates the importance of thorough cooling at the packhouse (Figure 1), as temperatures inside trucks often rose during transport (Figure 2).

Even packhouses that regularly use dataloggers were unaware of the extent of this issue, perhaps because temperature records have only been examined when there is a major failure. However, the results demonstrate that the effects of poor temperature management may only be observed once the fruit has ripened and softened, such as when it reaches the retail display.

The project has also demonstrated the effectiveness of forced-air systems for cooling before and after packing, as well as managing temperature during ripening. These systems can provide rapid cooling and heating with minimal additional investment.

The project results and recommendations have been summarised in high-quality grower-facing resources. These have filled a gap in previously available information, providing growers and packers with ready tools that they can apply in their businesses.

For example, it has long been strongly recommended that growers pick, pack and cool avocados within 24 hours. However, the packhouse studies indicated that many businesses were unable to achieve this rapid turnaround of fruit. While the preferred option remains the same (pick, pack and cool in <24 hours), alternative options are presented based on the pulp temperature of harvested fruit. So, if packing within 24 hours is not possible and fruit temperature is above 30ºC, then it is recommended to forced-air cool fruit to a temperature below 16ºC and pack within three days of harvest. This provides growers with alternative solutions that will maintain fruit quality.

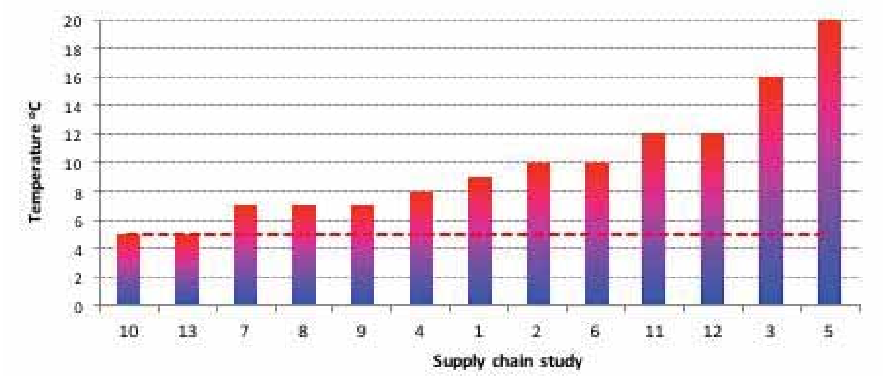


Figure 1. Pulp temperatures at dispatch from the packhouse in 13 supply chain studies: the red line indicates optimal temperature for Hass of 5ºC.

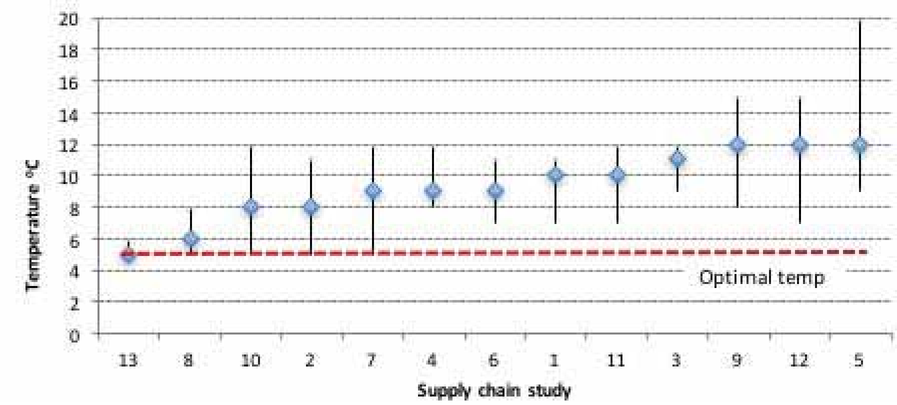


Figure 2. Average (◆), minimum and maximum air transport temperatures across 13 supply chains. The red line indicates the optimal temperature for Hass of 5 ºC.

Access to revised best new practice materials

The major outcome from the project is that Australian growers have ready access to the latest research on avocados, as well as clear and concise recommendations regarding maintenance of avocado quality from before flowering through to retail stores.

Local data has been collected to update and support best-practice recommendations grounded in international and local research. Examples include data on the impacts occurring during harvest and on packing lines, causes of skin damage during packing, cooling rates from different systems and the effect of poor temperature management on quality. Matching local data with more general observations ensures they are relevant to the Australian industry and gives credence to the resulting recommendations.

These recommendations have been communicated to growers directly – at the regional meetings, electronically through Avocados Australia communications, and in print through the best-practice resources. At this time, approximately 400 copies of each resource have been provided to growers and supply chain members, with more meetings and events still to come.

The AAL BPR has also been revised and updated as a result of the project findings, with the new resources added to the available downloads. These improvements are a direct outcome of the project.

Extension and implementation program – examples of change

The combined packhouse audit and best-practice guides are enabling growers and packers to identify improvement opportunities in their supply chains. Examples include:

- A grower/packer in North Qld who was applying a postharvest fungicide more than 24 hours from harvest. After coming to the presentation on the review of postharvest research, he learnt that most postharvest fungicides need to be applied to fruit within 24 hours of harvest for any control of fungal rots. The packhouse has since reduced their pick to pack time so that fungicide is applied within 24 hours of harvest.
- At one packhouse, potentially damaging impacts were found on one part of the packing line. The relevant chute has now been removed, avoiding this source of bruising.
- Another packhouse had issues with lenticel damage on the packing line. The project team helped identify the causes of the damage. As a result, the brushing system has been removed and line speed and loading altered. A major improvement has been reported this season.
- The difference in cooling speed and uniformity with forced-air compared to room-cooling was demonstrated through the packhouse studies and this has encouraged two packhouses to consider use of a forced-air system to cool picking bins before packing
- The packhouse studies have encouraged interest in use of temperature loggers throughout the supply-chain; in follow-up discussions with packhouses a number of them wanted more details on where to purchase loggers and advice on which types to use for regular monitoring in their supply chain.

Change will continue after the end of the project. Adoption of best practice throughout the supply chain is not achievable in a short period. However, this project has helped to increase grower aspirations, which will continue as a goal in the future.

As a result of the project, supply-chain members have increased their motivation toward improving fruit quality at retail, and improved their understanding of factors contributing to fruit damage. As Western Australian grower/packer Dudley Mitchell wrote in *Talking Avocados* magazine:

> *"Quality, however, must be kept at the forefront of everybody's mind as we try to do everything in our power to reduce the wastage at the retail end. A report on postharvest handling by Applied Horticultural Research has highlighted the potential for substantial damage to occur at picking, especially in cherry picker bags as fruit fall on to each other, as well as the potential for serious rots to occur from picking and storing wet fruit – these are things we can and must control at the grower level if demand is to be maintained and increased".*

Monitoring and evaluation

Overall project performance:

Increase adoption of cool-chain best-practice to reduce the level of damaged avocado fruit at retail from the current 25% (industry estimate) to no more than 10% within five years.

Has the project had any impact on the quality of fruit at retail?

The supply chain studies clearly showed that adopting best practice results in a significant reduction in the level of damaged fruit at retail. Best cool chain practice resulted in less than 10% of fruit damaged at retail, moderate levels of adoption of best practice resulted in 10-15% of the fruit at retail damaged, and poor practices led to more than 20% of fruit at retail damaged (Table 1 and Appendix 1).

The project has also verified that relatively simple changes in harvest and packing practices can significantly reduce bruising and skin damage.

The retail project (AV15011) demonstrated that quality at stores can be improved using sorted displays of fruit at different stages of ripeness; squeezing can be reduced by up to 40%, while the severity of damage to fruit on display was halved using sorted displays and appropriate signage.

There has been a high level of interest in the project findings, and it is expected that significant industry adoption will occur over the next 12 months. This will progress more quickly following the publication of the new best practice resources as well as the extension activities that have occurred since January 2018.

As this project has been going for less than two years, and extension activities have not been fully underway for a complete season, it is not expected that any major reduction in the percentage of damaged fruit at retail will have occurred at this time. Moreover, there is no current mechanism for assessing the percentage of damaged fruit at retail. However, continued extension with avocado supply-chains and a new monitoring program included as recommendations from this project.

Reviews and best practice resources

Have the best practice materials and research been reviewed?

The best practice materials and resources have been extensively reviewed by Australian researchers, avocado industry members, retailers and government representatives.

Did the reviews provide the necessary evidence for the design of other project components?

Comments from the reviews were incorporated wherever possible. Information was generated to fill gaps identified as part of these reviews where appropriate.

Have best practice materials been revised to a standard that meets industry requirements?

The best practice materials have been very well received and all feedback indicates they meet industry requirements.

Have the new best practice resources been effective ?

The new best practice resources have generated considerable interest. Attendances at regional meetings promoting the resources have been very strong, with some 426 growers, packers and supply-chain members attending. This is at least double the numbers that were anticipated.

Have the new resources been incorporated into supply chain practices?

A number of recommendations and changes have been incorporated into specific supply chains, with examples provided in the Outcomes section of this report. The resources are still very new, so other changes are likely to occur as the season progresses.

Extension and change program

Have the barriers to adoption been identified? Has the change program been developed and implemented?

Barriers to adoption and achieving practice change are summarised below.

Barrier to change	Change / communication program strategy
Lack of information	New best practice resources made available as printed hard copies and electronically through the Avocados Australia BPR, distributed widely through regional meetings and promoted through *Guacamole*. One-on-one meetings with key packhouses to present results of packhouse audits and temperature + quality monitoring.
Cost	Most proposed changes are likely to have a minor effect on production costs, e.g. dividing the picking bag during harvest from mechanical work platforms, shortening packing lines or adding extra padding. Other changes, such as increased use of forced-air cooling, involve an initial capital expense which would be recouped through electricity use efficiencies and improved outturn quality.
Lack of transparency in supply chains	Growers/packers are directly encouraged to make better use of temperature recorders, GPS locators and other technologies to check how well their product is managed. Recommendation to monitor retail quality in the future to provide direct feedback on product quality.
Lack of motivation to change	The regional meetings include a presentation from Avocados Australia Ltd CEO John Tyas on future directions for the industry. This makes it clear that while the industry has been highly profitable for the last few years, a large percentage of trees are less than three years old, with more still being planted. Many growers recognise that domestic demand and/or exports need to increase dramatically to preserve profitability. Quality is key to both of these strategies. In addition, conducting trials directly with major packhouses has helped to demonstrate the potential benefits of practice change. These factors should help provide motivation to adopt best practice.
Information not well understood	Information on best practice is provided clearly and succinctly, with diagrams and photographs used wherever possible. These make it easy to understand key points, even without reading all of the related text.

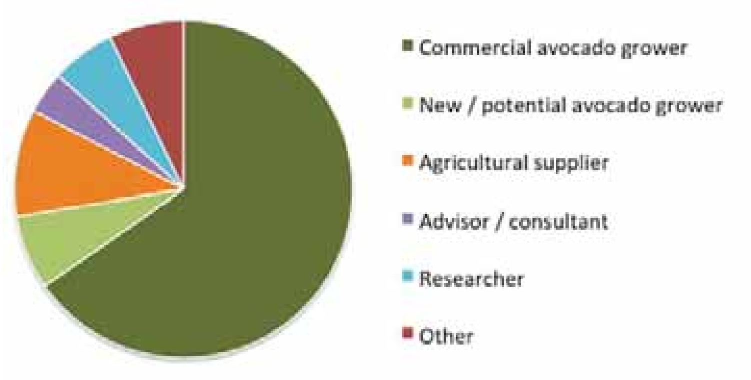
Working with 12 major packhouses has proven to be an effective strategy to bring about adoption of improved practices. These businesses have both the ability and motivation to adopt best practice and can act as supply chain captains in terms of delivering quality product to retail. Conducting trials directly with agronomists and packhouse managers has enabled both researchers and supply chain personnel understand what is required to optimise fruit quality through the supply chain.

The regional meetings have also proven very effective. Feedback forms filled in from the first four workshops confirm that the participants were satisfied with the content of the program, found the information useful and learned something new. Results are summarised below.

Feedback from Regional meetings in Crows Nest, Coolum, Bunbury and Renmark

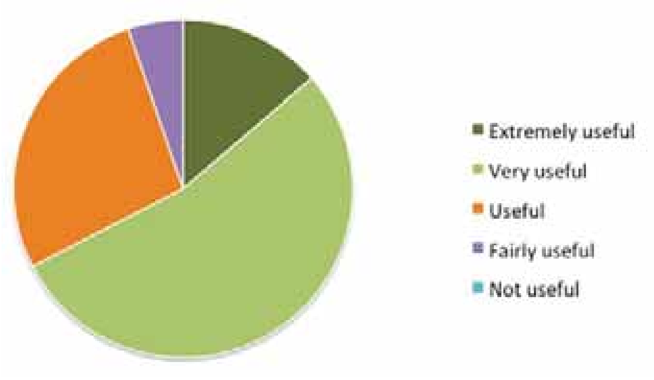
(n=98)

Role of participant



Which presentation was of most interest?

How useful was the meeting overall?



Did you learn something new?

Recommendations

1. Continued supply chain extension

This project has produced a high-quality, concise set of best-practice materials focused on the supply chain from harvest to retail. These materials have been well accepted by growers, packhouses and the retail sector with an estimated total of 426 growers, packers and supply-chain members attending seven regional meetings.

The best-practice materials are a good start, but implementation is vital and more is needed to translate these new resources into reducing damaged fruit at retail to less than 10%. The packhouse and supply-chain studies carried out at major packhouses was a useful extension tool and this could be expanded to other packhouses.

A group extension approach through regional masterclasses for managers and operations staff on effective supply chain management at each stage would help increase the reach of a future extension program.

An increasing number of packhouses are looking to export avocados. As a relatively high-cost producer, Australia competes on quality rather than price. This makes adoption of best practice essential for export. Additional training could be targeted at exporters, with the aim of ensuring they are export ready.

2. Quality monitoring program

This project had no component to monitor fruit quality at retail and, therefore, assess change. A quality monitoring program is required to determine if quality improves over the coming years as a result of the supply-chain improvement projects.

The supply chain studies included assessments of fruit quality through the supply chain and providing that information back to the packhouse. Packers found this information useful, as they currently have little feedback on fruit quality once it has left the packhouse. A monitoring program that includes rapid feedback to the grower and packer would allow identification and correction of supply-chain issues.

3. Effect of cooling method and delay after harvest on fruit quality

The packhouse studies identified that it is common practice for harvested avocados to be stored for a period before packing and cooling. Bins of fruit may be simply stacked inside cool-rooms, or even left under ambient conditions. While there is a stated objective to pick and pack within 24 hours, this is not possible at busy times of year or where orchards are remote from packhouses. Delays of several days are possible, during which time avocados may be only partially cooled.

Delays in cooling can allow fruit to break through the inhibition period and start to ripen. This is most likely in late season fruit. Uneven or inadequate cooling before and after packing also allows fruit to lose moisture, which can affect both yield and quality after ripening.

The effect of cooling delays between harvest and packing has been studied in both, South African and NZ-grown fruit. These have shown that stem-end rot and chilling susceptibility can increase significantly with cooling delays of more than 24 hours. While disease may be less of an issue in Australia than in NZ, harvest temperatures in Australia are often higher and humidity may be lower, increasing moisture loss. This very likely contributes significantly to uneven ripening after storage.

Work is required to examine the effect on fruit quality and yield of different cooling strategies after harvest. This should include trials testing the effects of cooling delays between harvest and packing, comparison of room cooling with forced-air and hydro-cooling, and cost:benefit analysis of different systems.

The project design should include examination of ripening uniformity (particularly for early and late season fruit) and logistical and quality issues associated with running cold fruit over a grading and packing line, e.g. sticker application to cold fruit changed susceptibility to bruising.

4. Monitoring of supply chain temperatures using new low-cost loggers with

GPS

The supply-chain studies identified serious issues with cool-chain management, particularly during transport. New low-cost loggers with GPS could be used to regularly measure temperatures of fruit in the supply chain from packhouse to retail. This would help growers and packers identify issues and also keep other supply chain partners "honest". Such a program could support an accredited supplier system.

5. Research needed in Western Australia

The review of postharvest research found that Australian research has primarily focused on fruit grown in South-East Queensland. In Western Australia, limited trials have examined productivity of different rootstocks and the effect of temperature.

However, approximately 40% of total national production is grown in WA, a region with very different soils and climate to growing areas in SE Qld. A dry climate combined with high temperatures during harvest may reduce disease pressure, but increase other physiological disorders.

For example, WA fruit may be optimally stored at either lower or higher temperatures than fruit grown in SE Qld; Dr Michael Considine, Senior Research Fellow at the UWA Institute of Agriculture**,** reported some preliminary data on the effects of growing temperature on quality of WA-grown Hass in 2004, but this does not appear to have been followed up in detail.

Research could be conducted in WA to "ground truth" (direct observation) conclusions from Qld research. This could include examination of disease management (pre- and postharvest), prevalence of different pathogens, the effect of high temperatures during harvest and optimising temperature management in domestic and export supply chains.

6. In-field NIR fruit dry matter assessment

Fruit that is harvested at low dry matter levels is poor-tasting and may not perform well when stored for longer periods. Avocado fruit maturity sampling is often based on only a few fruit per block, and time consuming assessment using a drier.

Portable near infrared (NIR) devices are now available which can measure dry matter instantly. An NIR device could enable assessment of dry matter in the orchard, allowing growers to identify areas of different maturity. The devices are GPS linked, so can create a "maturity map" of orchard areas.

Variability within batches is an important contributor to uneven ripening, which in turn reduces consumer confidence in fruit quality. Understanding how fruit maturity varies around the orchard would allow growers to schedule harvesting more appropriately. This would not only reduce the risk of harvesting low dry matter fruit, but also potentially improve the homogeneity of packed fruit.

7. Targeted postharvest disease management

The review of postharvest avocado research identified a need for more targeted disease management in Australia, based on regional and climatic variables.

Fungicides are commonly applied to Australian avocados to control stem-end rot and anthracnose. The pathogens that infect avocados are often latent diseases that do not develop until fruit starts to soften. Infection may have occurred during flowering, or early in fruit development. Non-systemic fungicides have limited effectiveness against diseases already established inside fruit.

The effectiveness of postharvest fungicides has been reported as around 50% or less. These studies often applied fungicide immediately after harvest; in reality, fungicides may be applied several days later. In other crops, fungicide applications more than 24 hours after harvest have been shown to have little effect.

Application of fungicides during flowering may therefore be a better way to control postharvest diseases than postharvest applications. In addition, pathogen load is likely to vary with environmental conditions, with dry areas having lower pathogen loads in general.

Late applications of postharvest fungicides may therefore be ineffective, yet add costs during packing. Future work should examine whether delays in application reduce the effectiveness of postharvest fungicides against both body rots and stem-end rots. This could provide growers with better guidance as to appropriate use of different postharvest fungicides.

8. Novel disease management options

The disease control review identified a number of novel disease-management options that may warrant further investigation for their potential application in the avocado industry, including:

- New biocontrol agents or application options
- Closer examination of essential oils such as thyme oil and lemongrass oil
- Determination of the fungicide resistance status in pathogens causing fruit-rot diseases in Australia
- New fungicide options or a combination of conventional fungicides with biocontrols
- Investigation of the fungal pathogen genome to identify targeted solutions to disease control (Beever et al, 2005)
- Investigation of the avocado genome to identify areas to be targeted for resistance breeding
- Further investigation into the genetic provenance of the rootstock.

Research in other fruit growing crops may have potential for application within the avocado industry. Some novel approaches for disease management that could be further investigated for the application to the avocado industry may include:

- Application of bicarbonate solutions (including ammonium-, potassium- and sodium-bicarbonates) has been shown to control fungal diseases on grapes, cucurbits, citrus, strawberries and peppers and the mode of action of such solutions involves moderating the pH on the leaf/fruit surface, inhibiting fungal growth
- Application of clay-based products has provided effective fungal control on apples and grapes; the mode of action for these preparations involves increasing the concentration of aluminium on the plant surface (resulting in increased uptake of aluminium) and acidifying the pH on the plant surface, inhibiting fungal growth –commercial brands such as Ulmasud® and Myco-Sin® were tested (Schmitt et al. 2002, Hofmann, 1996)
- In apples, a yeast pheromone and a peptide molecule similar to that found in *C. gloeosporioides* can inhibit the development of appressoria, providing a new direction for biological control research (Al-Samarrai et al, 2002).

9. Developing a predictive model of disease potential

Given the importance of nutrient interactions in reducing disease incidence Dann et al. (2016) believes there may be a potential to measure the ratio of nitrogen:calcium in the skin of unripe avocado to provide an indicator of potential disease occurrence in fruit after harvest. Everett et al. (2003) has suggested that measuring levels of fungal pathogens present on the leaves during the production season may provide a potential indicator of postharvest rots. There was some variation in the level of inoculum depending on where the sample came from, e.g. near or far from the ground, position within the canopy, even what part of the leaf was sampled. While a correlation was found between the levels of anthracnose and *Botryosphaeria spp.* found, and the level of post-harvest rot detected, this area requires more refinement before it can be used as a practical predictive tool.

Refereed scientific publications

None to report.

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Intellectual property, commercialisation and confidentiality

The program reference group have requested that some of the outputs from the project remain available only to those within the Australian avocado industry. Those outputs include:

Pre and Postharvest Management of Avocados – Review

Australian Avocado Supply Chain Best Practice Guide

Avocado Fruit Quality Problem Solver Guide

Australian Avocado Supply Chain Checklists

These outputs will only be available electronically from the Avocados Australia Best Practice Resource, which requires login access. Hard copies will only be distributed to Australian avocado supply-chain stakeholders.

Acknowledgements

This project would not have been possible without the generous assistance and cooperation of the many packhouses and their staff who were involved in the supply chain studies. Many members of the avocado industry – particularly the Project Reference Group (PRG) – also provided valuable feedback on the many drafts of the best-practice resources, particularly the main guide. These comments greatly improved the end product and ensured that the information was consistent and practical.

The project team would also like to thank the staff at Avocadoes Australia, for their feedback on the best practice resources, help with incorporating these resources into the online BPR, promotion of the project through newsletters and emails, and, most importantly, the rollout of the materials at the regional meetings.

Produce Marketing Australia, for their insights into marketing and valuable report on avocado handling by Mission Produce and other international companies.

Finally, the Queensland Department of Agriculture and Fisheries (QDAF) who provided the building blocks of information that became the “Checklists” document, as well as a great deal of technical advice, provision of photographs, and other inputs into the best-practice resources generally. QDAF researchers conducted much of the research that now forms the basis of our best-practice recommendations, and this invaluable contribution to the future of the Australian avocado industry is gratefully acknowledged.

Appendices

Publications (provided separately)

These have been provided separately as they should **only** be made available to Australian avocado industry. They are available electronically from http://www.avocado.org.au/best-practice-resource/library/ which requires login access (at the time of publication, hosting being configured by AAL).

- Stages of Ripeness Chart

Reports

- Appendix 1 – Packhouse studies report
- Appendix 2 – Review of existing avocado best practice resources
- Appendix 3 – Research gaps summary
- Appendix 4 – Disease control review
- Appendix 5 – Mission Produce visit report

Presentations

- Grower/packer presentations
  - Appendix 6 – Atherton avocado grower meeting – 3 May 2017
  - Appendix 7 – Bundaberg avocado study workshop – 17 August 2017
  - Appendix 8 – Regional extension workshops – May/June 2018
- Project reference group
  - Appendix 9 – PRG meeting 13 February 2017
  - Appendix 10 – PRG meeting 14 August 2017
  - Appendix 11 – PRG meeting 14 March 2018
- Retailers
  - Appendix 12 – Presentations to retailers – March 2017
- Other
  - Appendix 13 – R&D forum in Brisbane – 8 November 2017
  - Appendix 14 – Sydney University Institute of Agriculture – 27 March 2018

Articles

- Appendix 15 – *Talking Avocados* articles
  - Winter 2017 – "Avocado supply chain improvement projects are well underway"
  - Summer 2018 – "Avocado cool chain best practice adoption"
  - Autumn 2018 – "New avocado supply chain resources"

Monitoring and evaluation

- Appendix 16 – MERI plan

1 AV15010 – Packhouse studies report

1.1 Introduction

This project has focused on increasing the adoption of best practice along the supply chain, with the aim of reducing the amount of damaged fruit at retail.

The packhouse has a major influence up and down the supply chain; across growers, transporters, ripeners and, to some extent, retailers. Therefore, an extension program targeted the major avocado packhouses in each growing region.

Engagement was through a study of the packhouse supply-chain practices from harvest to retail, with a focus on temperature management. Packhouses were provided with a detailed report on the findings, with issues and recommendations for improvements identified.

As those reports were provided confidentially to the packhouse only, this report de-identifies the packhouses involved. It provides an overall summary of practices assessed at each packhouse/supply chain and, wherever possible, links those practices to fruit-quality assessments. See Table 2 for an overall summary of practices and quality.

1.2 Methods

1.2.1 Participating packhouses

Avocado packhouses were invited to participate via Avocados Australia *Guacamole* newsletter and *Talking Avocados* magazine. In addition, the 12 largest avocado packhouses in Australia (covering all major growing regions) were contacted and personally invited to participate in the studies. All up, 12 packhouses across five states participated in the studies as follows:

Region	Packhouses (no.)	Date (2017)
North Qld	3	May
Central Qld	3	July to August
Central NSW Coast	2	September
Riverland SA	1	October
Southwest WA	3	November

Each packhouse was visited during the harvest season. A selection of practices were assessed depending on the needs of each business, the availability of equipment, and supply chain logistics. Overall, the 12 studies included the following number of assessments:

- *Fruit handling and impacts*
  - Harvest impacts 2
  - Bin compression damage 1
  - Packing line impacts 8
  - Lenticel damage along packing line 1
- *Temperature management*
  - Cooling before packing 9
  - Cooling after packing 9
  - Transport temps 13
  - Ripening temps 6
  - Ripener-to-retail temps 3
- *Fruit quality assessments through the supply chain – 7*

1.2.2 Fruit handling and impacts

Impacts at harvest

A Techmark impact recorder was added to the top, middle and bottom of mechanical work platform (MWP, also known as a cherry picker) bags and then emptied into half-full or empty picking bins. This was repeated 2–3 times for each position in the bag.

To simulate a fruit being dropped into an MWP and ground bag, the impact recorder was dropped into an empty mechanical work platform and ground bag (with a single layer of fruit in the bottom), and then a half-full MWP bag. This was repeated three times.

Maximum G-force and velocity change were both recorded. This data was graphed according to the MaxG recorded.

Figure 1. Dropping fruit into a full-depth mechanical work platform bag.

Bin compression damage

At one packhouse, flat spots/compression damage symptoms were observed on incoming fruit from a particular supplier.

To try and identify the cause of this damage, two bins of fruit were examined before packing. Fruit was removed from bins and assessed for compression damage, noting location in the bin.

A sample of fruit with compression damage symptoms was taken back to the AHR laboratory, ripened and assessed for internal damage.

Packing line impacts

A Techmark impact recorder was run down the packing line in appropriate sections (x 3). After an initial run through the whole line, potentially problematic areas were identified and the ball re-run focusing on specific drops.

Time stamped maximum G-force and velocity change were recorded. This data was graphed according to the MaxG recorded at each impact point.

Previous work had shown that a >180G impact recorded using the Techmark IRD is equivalent to a 10cm drop onto a hard surface. This is sufficient to cause a small bruise on a hard-green avocado, even though that bruise does not become evident until after ripening.

To establish the damage threshold, hard-green avocados were dropped onto a hard surface from increasing heights. Bruising was evident in some fruit from 15cm, which was equivalent to an impact of 200G.

Where potentially damaging impacts (>200G) were identified, fruit samples were retrieved from before and after the impact, ripened and assessed for damage.

Figure 2. Techmark impact recorder on packing lines.

Lenticel damage

Although lenticel damage on Hass fruit becomes less obvious as the fruit ripens, it nevertheless could contribute to increased moisture loss and disease, as well as appearing unattractive when fruit is delivered to ripeners. One of the packhouses studied had experienced significant issues with lenticel damage, but was unsure of the cause of this problem.

In order to identify the cause of lenticel damage, two trays of avocados were taken on four different packing days from the following positions along the packing line:

1. Direct from bin
2. Bin tip
3. Fungicide
4. Brushing
5. Drying
6. Packing

Fruit was transported to Sydney and assessed in hard-green condition. The number of damaged (rubbed or broken) lenticels were counted on 10 fruit from each tray using a 5cm^2 circle on three random locations on each fruit. The three values were averaged to give the average number of damaged lenticels in a 5cm^2 area per fruit.

Samples from one packing date were ripened to identify any effect of the lenticel damage on fruit quality when ripe.

1.2.3 Temperature management

Temperature from harvest to packing

Probe and air temperature loggers were added to fruit inside three bins picked during the middle of the day in the orchard. Test avocados were placed inside mesh bags, which were packed into approximately the centre and top of each bin.

Picking bins were then taken back to the packhouse and cooled or stored as usual until packing. Recorded temperatures were then compared between the middle and outside of the bins.

At one packhouse, the cooling of fruit in a forced-air cooler and passive room-cooling were compared.

Figure 3. A marked bin (left) and data logger with probe used to monitor temperatures of fruit inside (right).

Temperature management from packhouse to ripener, wholesaler, and retailer

After packing, probe and air-temperature loggers were added to two packed trays per pallet. In most cases, two pallets were monitored. Trays were placed at least four trays below the top of the pallet, with one in the middle stack and one in the corner stack.

Real-time Locus Traxx GPS and temperature loggers were also added to trays in nine supply chains to track location and temperature in real-time.

Once loggers were added at the packhouse, trays were sent along with a standard shipment of avocados to the ripener/wholesaler (mostly Sydney-based).

Temperatures were then monitored through the ripening process, and all reusable loggers were removed once fruit had been cooled after ripening. Where disposable real-time Locus Traxx loggers were included, temperatures were also monitored from ripener to the retail distribution centre and into retail stores.

Figure 4. Example of real-time GPS tracking and a locus Traxx data logger (right).

1.2.4 Fruit quality assessments

Fruit quality was compared along the supply chain of seven supply chains, with two trays per supply chain stage collected and labelled as follows:

- Avocados taken directly from the bin ➔ Packed into tray ➔Transport direct via air/car to Sydney ➔ Cool-stored at 5°C until fruit that had been trucked to Sydney went into ripening ➔ Ripening
- Avocados taken from the end of the packing line ➔Transport direct via air/car to Sydney ➔ Cool-stored at 5°C until fruit that had been trucked to Sydney went into ripening ➔ Ripening
- Avocados packed as normal ➔ normal truck transport to Sydney ➔ Ripening
- Avocados packed as normal ➔ normal truck transport to Sydney ➔ Ripening ➔ Retail store

Fruit that had been normally transported to Sydney went into ripening along with the samples that had been transported direct via air to Sydney. The trays were then pre-cooled, and transported to the Sydney University laboratory for assessment of internal defects.

Samples of 20 fruit/treatment were assessed once the fruit had reached edible-soft. Fruit was cut into quarters, the skin removed and the fruit examined for signs of rots, bruising or other internal defects. If any were detected, the damaged area was scooped out and weighed using an analytical balance. The remaining fruit flesh was also weighed, allowing calculation of the percentage damaged flesh/fruit.

1.2.5 Reporting

A confidential report of findings and recommendations were provided to each packhouse on completion of the study, and a follow-up discussion held.

1.3 Results and discussion

1.3.1 Fruit handling and impacts

Impacts at harvest

The main harvest impact of concern was the dropping of fruit into full-depth (empty) MWP bags. The drop is over 1m, and results in impacts well over the damage threshold (200G) where bruising may occur, and skin damage certainly would.

Halving the height of the drop reduced the impacts back to safe levels, as did picking using ground bags (Figure 5). Rope extenders that gradually lower the depth of the bag should always be used to minimise impacts on fruit at harvest.

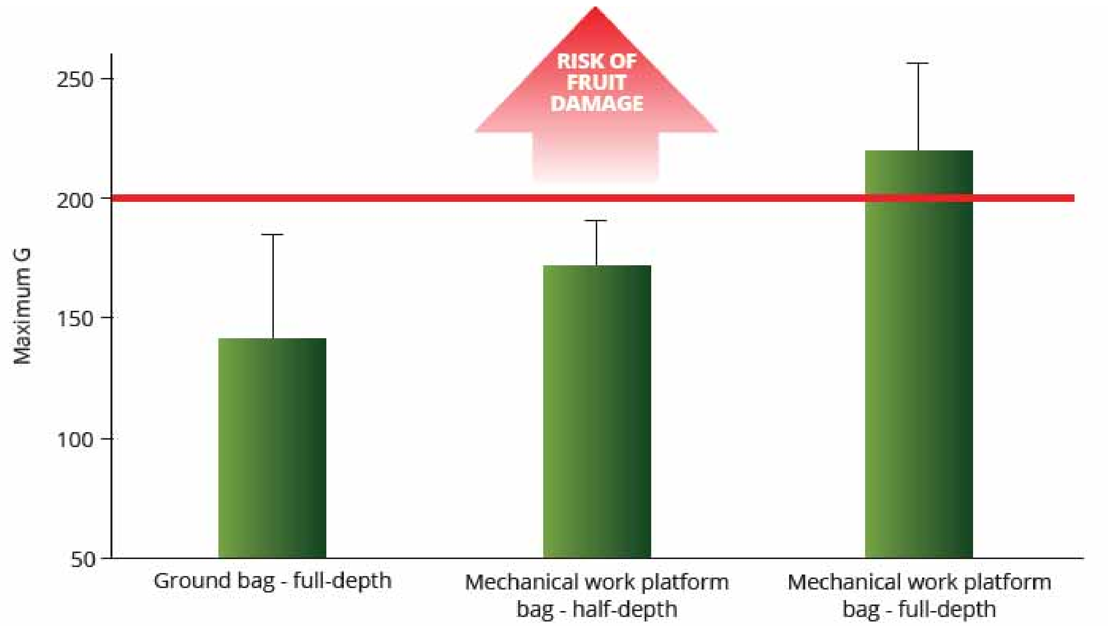


Figure 5. Impacts over 200G have the potential to damage fruit, with injury most likely once impacts exceed 250G. Fruit harvested into empty, full-depth (1m drop) mechanical work platform (cherry picker) bags often result in impacts >200G. Halving the height of the bag using rope extenders, or harvesting into ground picking bags, reduces impacts to safe levels.

When emptying MWP bags into half-full bins, impacts were well within acceptable levels. However, the risk of damage increased when tipping bags into empty picking bins, most likely a result of fruit rolling in the empty bin (Figure 6). Care should therefore be taken to empty fruit slowly, particularly when the first few bags of fruit are emptied into the bin.

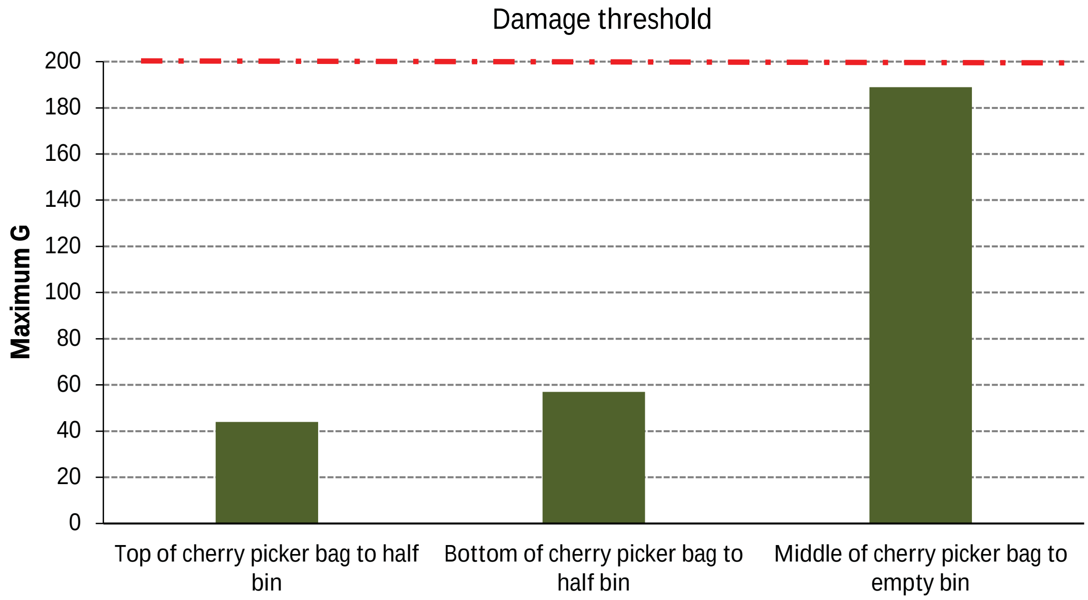


Figure 6. Impacts measured from the top, middle or bottom of a cherry picker (mechanical work platform) bag, when emptied into half-full or empty picking bins. The main risk of damage was when fruit was tipped into an empty bin.

Bin compression damage

Levels of flat spots or compression damage were highest in the lower quarter of the picking bin. Careful examination of the fruit inside the bin indicated that this damage had occurred during transport to the packhouse, being focused on touch-points between fruit. It is unclear why this problem occurred in some batches of fruit and not others, but it likely relates to the firmness of the skin. Fruit that are harvested during or soon after rain/heavy irrigation are likely to have softer skins, which may be more susceptible to compression damage. In this case, the region had had significant rain in the weeks leading up to harvest, even though the fruit was dry when picked.

Figure 7. Avocados with flat spots in the top (a) centre (b) lower-centre (c) and base (d) of a bin delivered to the packhouse.

Figure 8. Close-up of flat spot symptoms on fruit.

Despite what appeared to be significant damage at harvest, samples of fruit with compression damage that were taken back to Sydney did not develop any internal flesh damage directly underneath the compression spot. It was therefore concluded that this damage is superficial only, with the fruit fully recovering during postharvest storage and ripening.

Packing line impacts

Impacts were well below the damage threshold (200G) on most packing lines. An example of a typical packing line is shown in Figure 9. Out of eight packing lines assessed, only one line had impacts that were likely to be damaging fruit. This occurred where second-grade fruit was dropped down a long chute at grading (Figure 10). Samples taken from after the chute showed higher levels of bruising, with half of the sample affected.

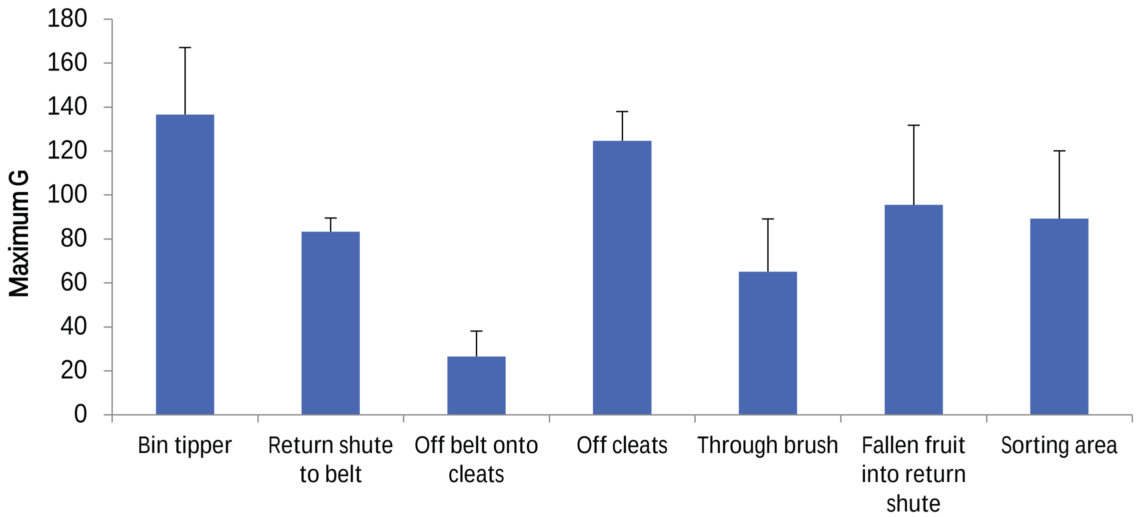


Figure 9. Typical impacts recorded along a packing line from bin tip to packing. Average (n=3 to 7) maximum G recorded using a Techmark IRD. Bars indicate the standard deviation of each mean value.

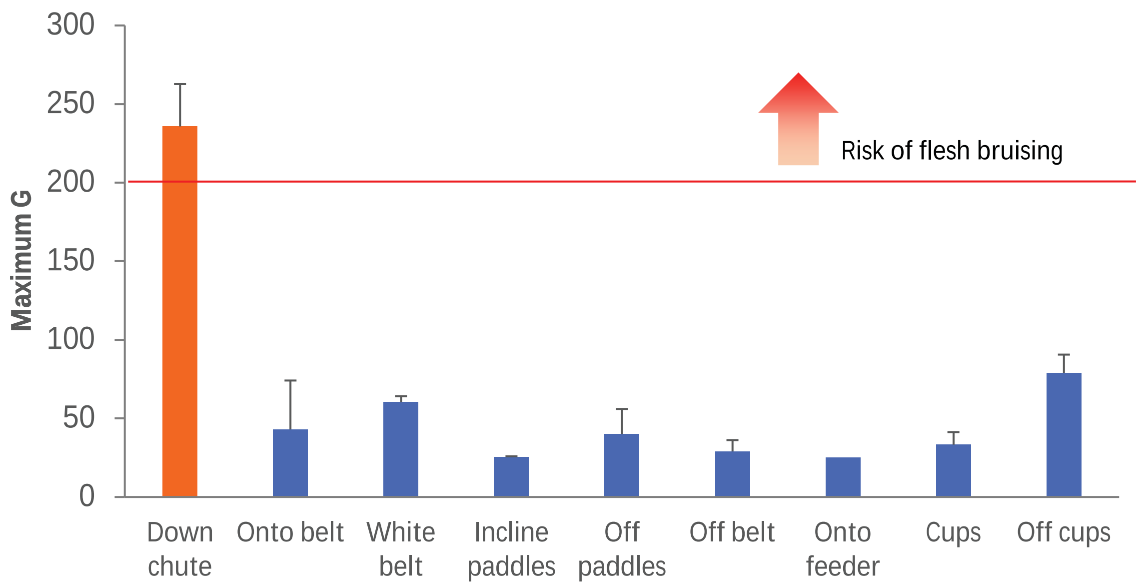


Figure 10. Average (n=3) maximum G recorded using a Techmark IRD along a Class 2 packing line (bars indicate the standard deviation of each mean value).

On many packing lines, the highest impacts were recorded at the bin tipper. Different types of bin tips were assessed, including wet tips, and dry tips, with or without a cover over the bin. However, the type of bin tip did not appear to influence the impacts measured (Figure 11). As an observation, lower impacts were more likely on tippers that slowly tipped the bin, and left small gaps between fruit coming out of the bin and fruit already on the feed belt. Larger impacts were noted where fruit fell from the bin, impacting other fruit below.

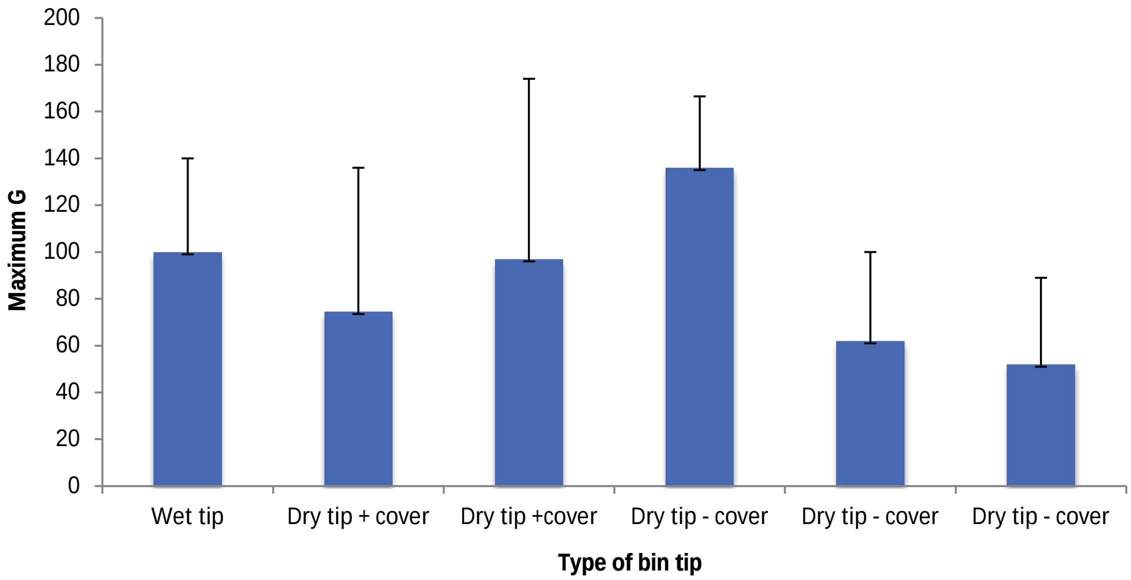


Figure 11. Average (n=3) maximum impacts recorded at the bin tip in 6 packhouses. Maximum G recorded using a Techmark IRD (bars indicate the standard deviation of each mean value).

Lenticel damage

Samples retrieved at different points along the packing line indicated that much of the damage was likely due to fruit rolling and rubbing against each other. The action of brushes during fungicide application and cleaning along the packing line also likely contributed to the damage, with these two factors causing most of the damage (Figure 12).

Damaged lenticels provide an entry point for avocado fruit-rot pathogens. Therefore, some of the fruit that had been collected at different points along the packing line was ripened and assessed for rots. However, no clear differences in levels of rots were identified, and once fruit was ripe, lenticel damage was less obvious.

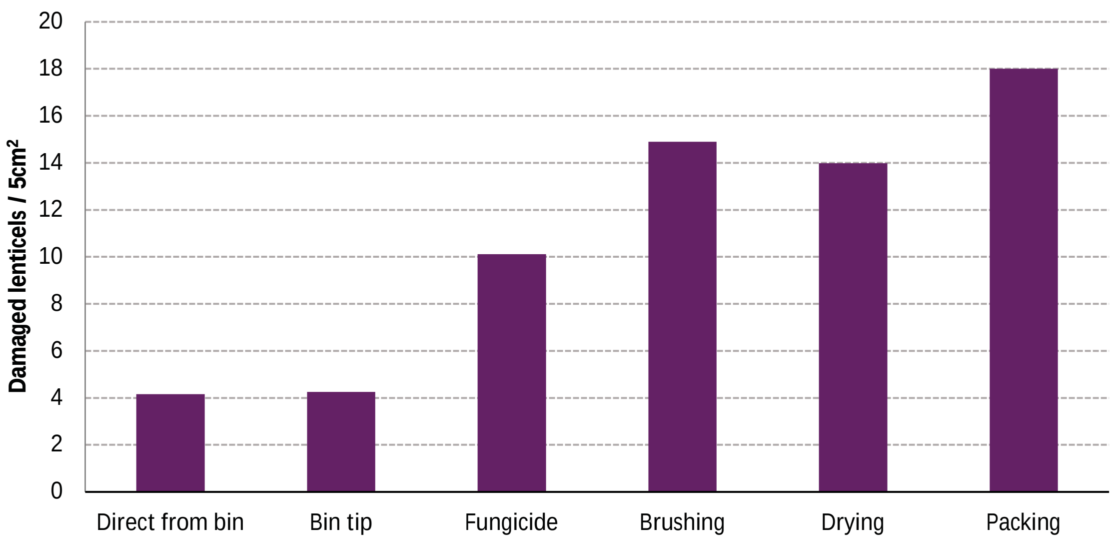


Figure 12. Average number of damaged or marked lenticels in a $5cm^2$ circle on a fruit (n=20) at sequential points of a packing line.

1.3.2 Temperature management

Temperature management from harvest to packing

Avocados should always be packed and cooled within 24 hours of harvest if possible. However, that is not always commercially feasible, and was not the case for most of the packhouses assessed.

The next best option is to cool the fruit and pack it within three days. Most packhouses were doing this, although using room-cooling rather than forced-air. Room-cooling was slow, and unevenly cooled fruit within the picking bin (Figure 13). The temperature gradient that develops between the middle and outside of the picking bin is possibly a contributor to fruit ripening variability, as this will alter the rate of breakdown of the "tree factor" that inhibits ripening of avocadoes. It's likely that fruit which remains warm for longer after harvest due to position inside the bin and/or cool room will ripen more quickly once removed to warmer temperatures.

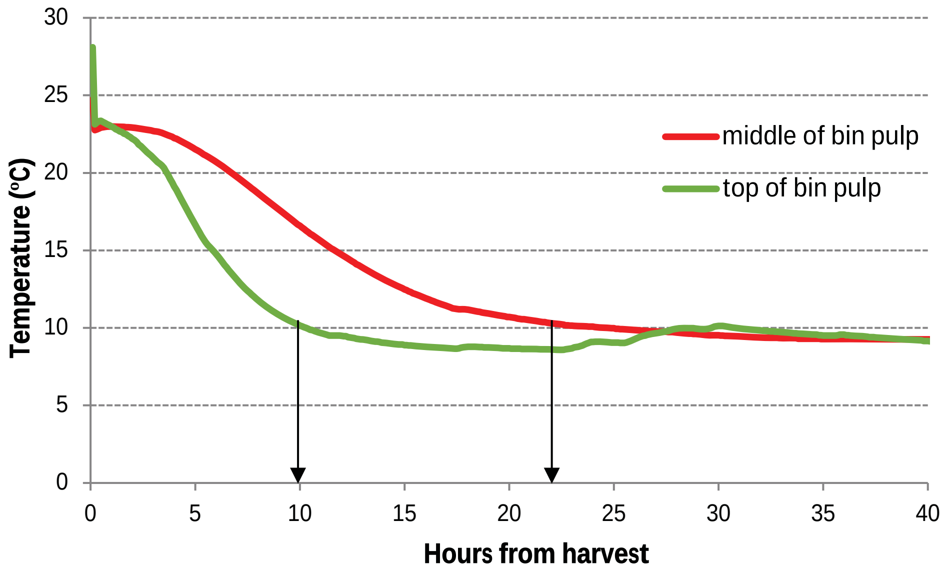


Figure 13. Pulp temperature of avocados in the middle or top of picking bins that were room-cooled. Fruit in the top of the bin reached 10 °C within 10hrs, versus 22hrs for fruit in the middle of the bin.

Only one of the 12 packhouses studied was using a forced-air system for cooling picking bins. This practice resulted in more rapid and even cooling of fruit throughout the picking bin (Figure 14).

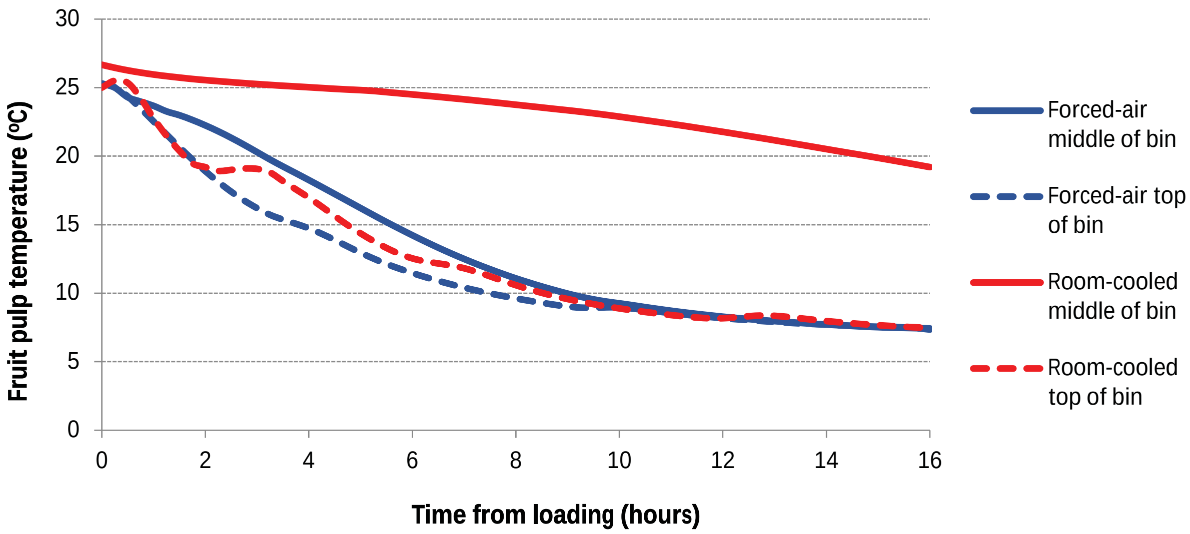


Figure 14. Pulp temperature of avocados in the middle (solid line) or top (broken line) of picking bins forced-air or room-cooled within the same storage room.

Temperature management from packhouse to ripener/wholesaler, and retail

Most packhouses failed to cool the fruit to the recommended temperature of 5°C before transport, with four packhouses dispatching fruit while it was still above 10°C (Figure 15). That was often due to the fruit being dispatched soon after packing and relying on room-cooling rather than a faster forced-air system. Some packhouses do not cool packed fruit at all, but rely on cooling during storage at transport depots combined with truck refrigeration systems during transport.

In some cases, fruit was cooled well below 10°C after packing, but then re-warmed by up to 5°C due to extended exposure to ambient temperatures at dispatch.

Trucks are ineffective at cooling and should only be relied on to maintain temperature. Therefore, fruit from packhouses that failed to dispatch fruit at close to 5°C risked fruit starting to ripen during transport.

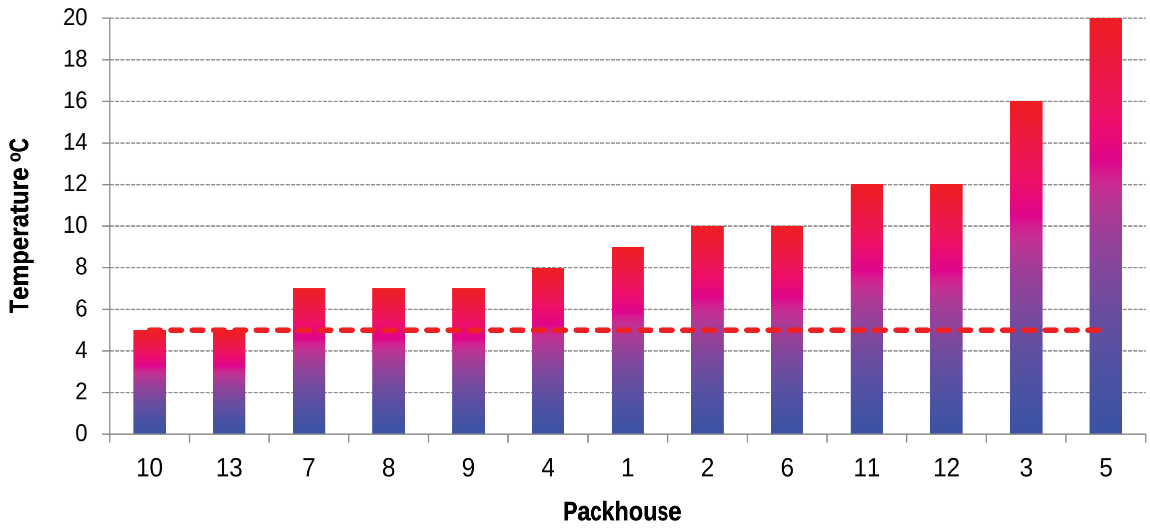


Figure 15. Pulp temperatures at dispatch from the packhouse: the red line indicates optimal temperature for Hass of 5°C.

Only one out of the 13 supply chains that was monitored maintained fruit consistently at the recommended temperature of 5°C. For most supply chains, transport temperatures were well above 5°C, with almost half averaging 10°C or higher (Figure 16). There were also large fluctuations in temperature, with some fluctuating by 6°C or even greater.

High transport temperatures were possibly a result of incorrect truck settings, lack of cooling capacity, poor internal air circulation or refrigeration being switched off. As a result of those issues, most temperatures gradually rose through transport, as per the typical example shown in Figure 17.

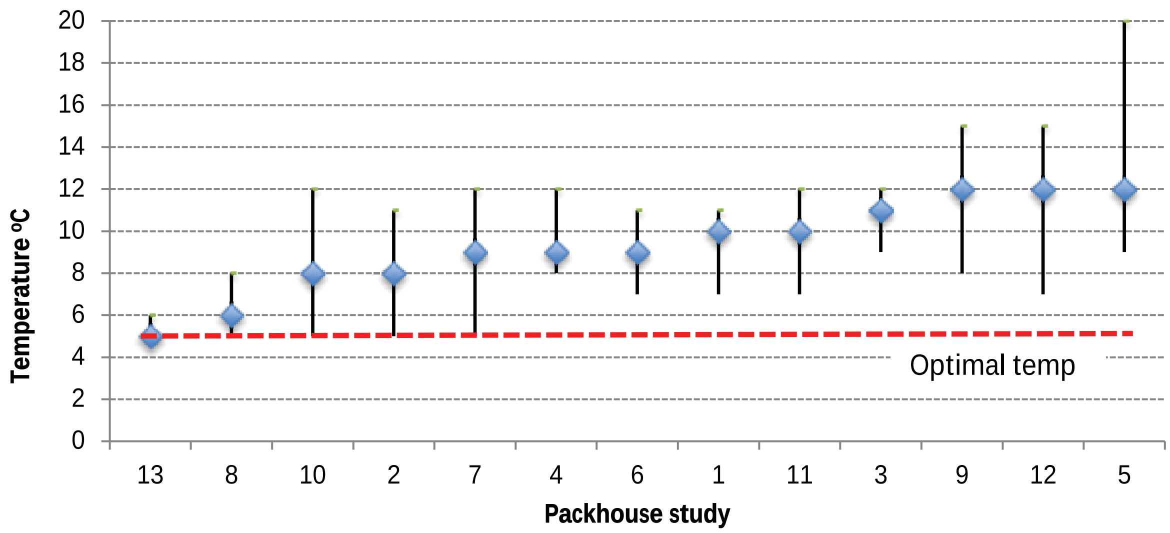


Figure 16. Average (◆), minimum and maximum air transport temperatures across 13 supply chains. The red line indicates the optimal temperature for Hass of 5 °C.

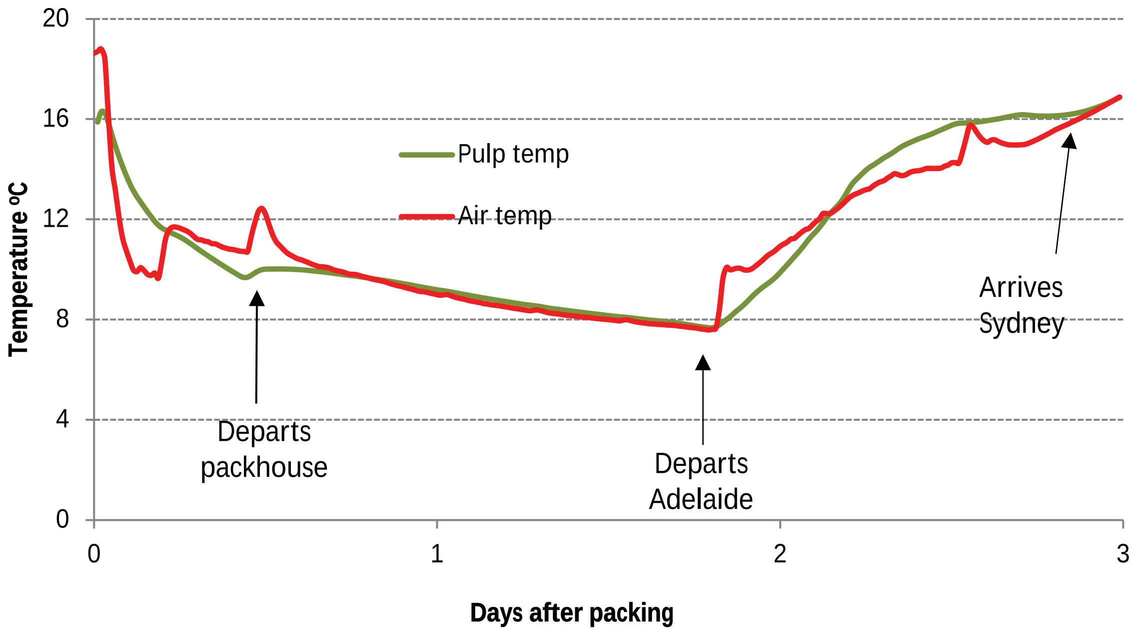
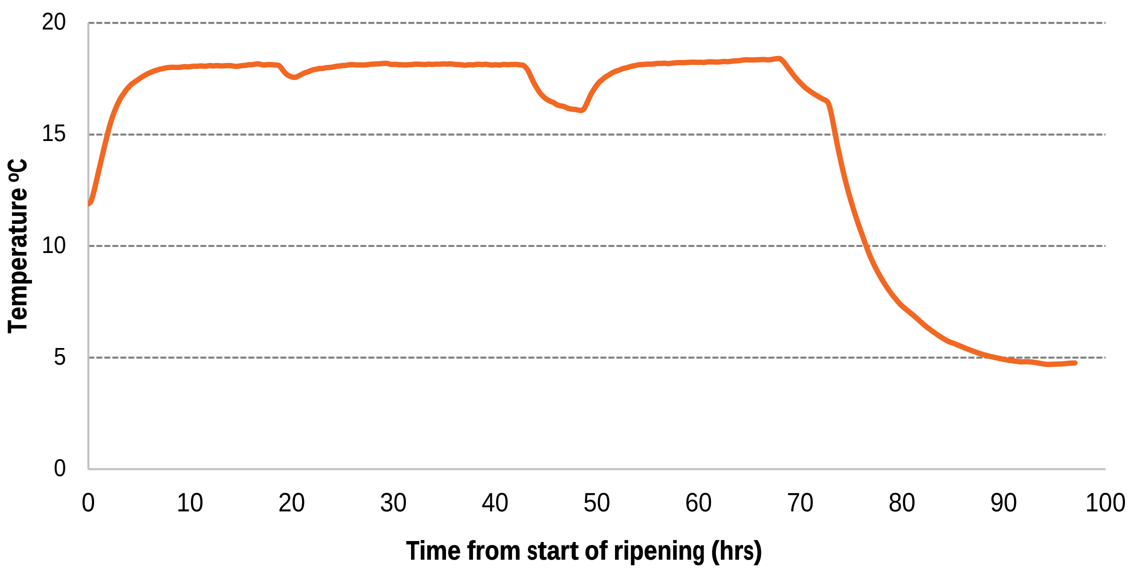


Figure 17. Transport temperature log, where temperatures gradually increased from Adelaide to Sydney.

Ripening temperatures varied between ripening facilities. Some followed best practice and used forced-air systems to rapidly and uniformly raise temperature to 18°C and then hold it there. Others left fruit to warm up passively, resulting in slower warming and temperature fluctuations during ripening (Figure 18).



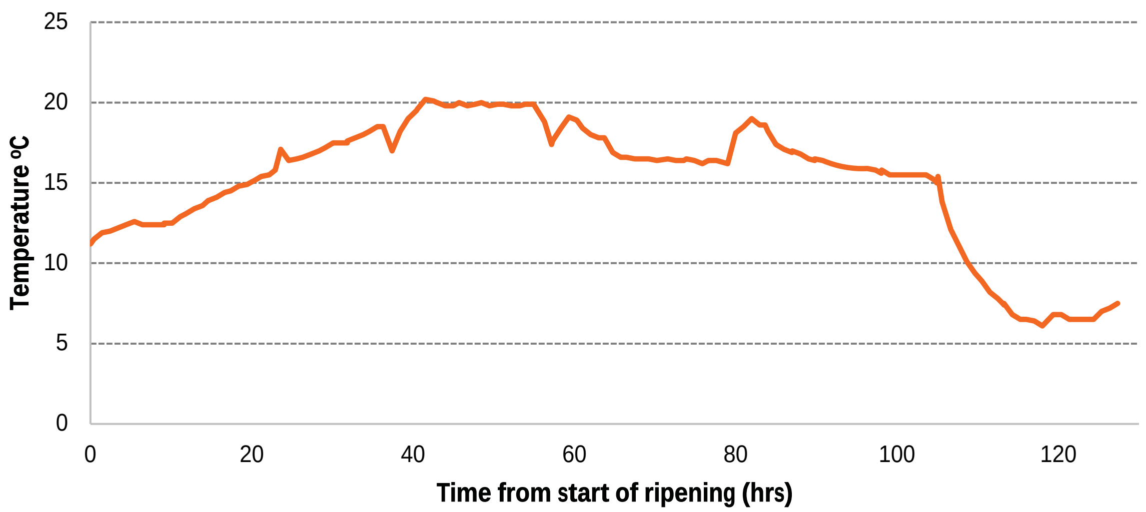


Figure 18. Fruit pulp ripening temperatures at two different facilities. The first used forced-air to warm fruit and maintain temperature (top) and the other let fruit temperature increase passively (bottom).

Only three supply chains were assessed between ripener and retail store. However, all of them were short and maintained the cool chain. As one example, fruit arrived to the retail DC at 8°C, was maintained at that temperature and dispatched to a retail store within five hours. Fruit was kept somewhat refrigerated, and was placed on store display within seven hours of receival (Figure 19).

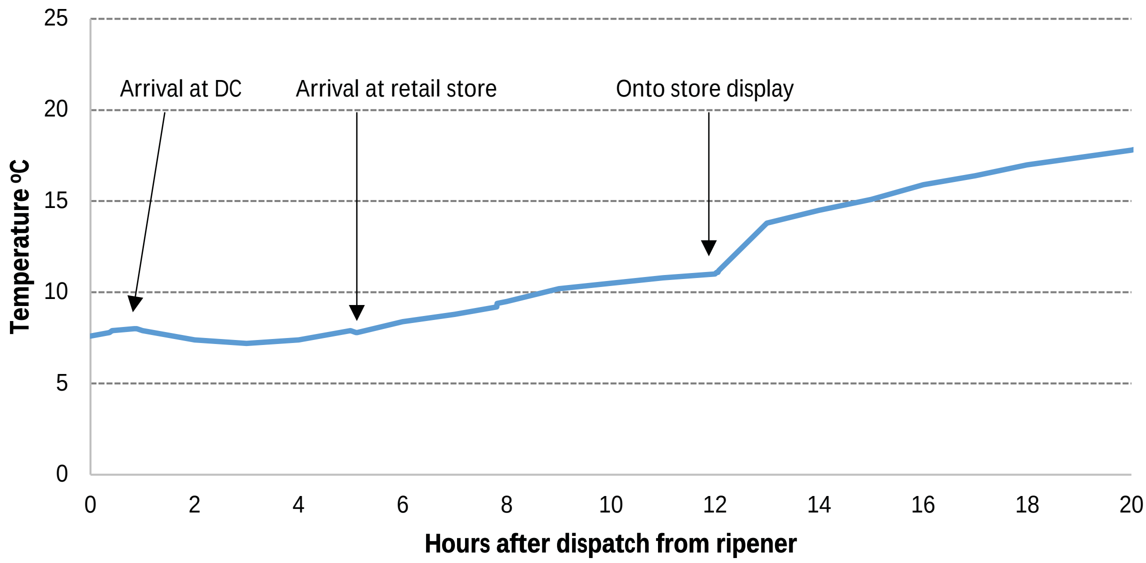


Figure 19. Air temperatures from retail DC to retail store.

1.3.3 Fruit quality and effect of supply chain practices

Fruit samples were collected from the picking bin, after packing, transport and retail; then ripened and assessed for internal damage. While that provided a snapshot of quality at one point in time, it should be recognised that this by no means provides an overall level of quality for each packhouse.

There was a large range in fruit quality between packhouses, and it was difficult to make comparisons between them, due to differences in length of supply chains and fruit age at time of assessment.

However, the data was useful for each individual packhouse, as fruit quality assessments were often indicative of practices followed in the supply chain. For example, in some supply chains, a low incidence of damage was evident at all stages (e.g. packhouses 4, 6, 7, 8), suggesting that supply-chain practices were maintaining fruit quality (Table 1). However some packhouses had an increase in damage along the supply chain (e.g. packhouse 5), suggesting that supply-chain practices were reducing fruit quality. Others had high levels of damage right across the supply chain (e.g. packhouse 10), suggesting a pre-harvest issue was the cause of the damage, or postharvest control of rots was insufficient.

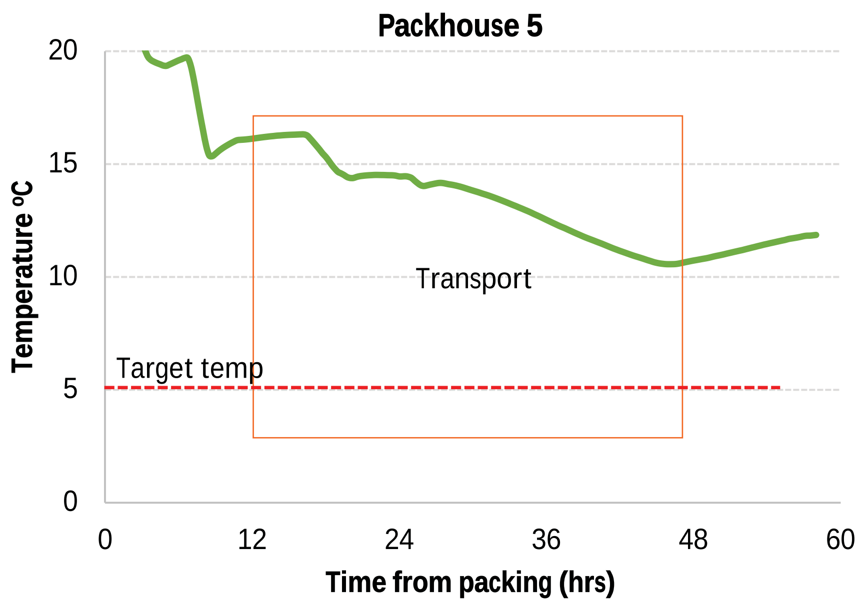
Supply chain practices and resulting fruit quality are summarised in Table 2.

Table 1. Number of avocados (out of 20) with flesh damage collected after three stages of the supply chain at each packhouse. Fruit was ripened and assessed at the soft-ripe stage.

Packhouse	Picking bin	Packing	Transport	Retail
4	NA	1	1	0
5	NA	1	5	6
6	2	3	3	2
7	NA	2	2	1
8	3	2	3	NA
9	10	7	9	NA
10	20	18	11	NA

In one case, a comparison between two packhouse supply chains was possible as the supply chains were the same length and originated from the same region. Significant differences in quality through the supply chain were evident, where quality from packhouse 6 was maintained through the supply chain, while fruit quality of packhouse 5 declined, particularly between the packhouse and post transport assessments.

The main difference between these two supply chains was the average transport temperature (Figure 20). This suggests the cause of the quality issues for packhouse 5 was poor temperature management during transport.



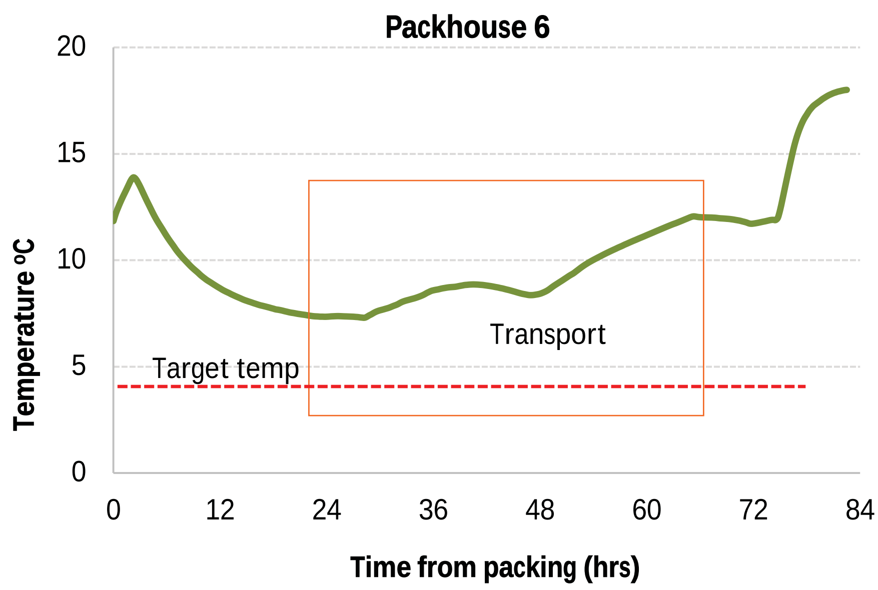


Figure 20. Transport temperature profile for packhouses 5 (top) and 6 (bottom). Packhouse 5 was further from the target temperature of 5ºC than packhouse 6.

Table 2. Summary of packhouse and supply-chain practices, and resulting internal fruit quality from studies across 12 Australian packhouse supply chains.

Key: Consistent with best practice; Improvements required; Issue that is likely to reduce fruit quality or needs urgent improvement

*Supply chain length - Long: >2000km, medium: 1000-2000km , short: <1000km

Packhouse	Supply chain length*	Harvest impacts	Impacts along packing line	Cooling before packing	Cooling after packing	Transport temperatures	Ripening temperatures	Ripener to retail temps	Internal damage at ripe
1	Long			No, but pick to pack < 24hrs	9°C within 20 hrs	**Avg: 10°C** Min: 7°C Max: 11°C			
2	Long				10°C within 24 hrs	**Avg: 8°C** Min: 5°C Max: 11°C			
3	Long			No, but packing within 24hrs	None, loaded @ 16°C	**Avg: 11°C** Min: 9°C Max: 12°C			
4	Medium			Room cooling to 10°C within 15 hrs	8°C within 16hrs	**Avg: 9°C** Min: 8°C Max: 12°C	Forced-air warming to 18°C, then down to 5°C	4-8°C at retail DC and in to store	Low at ripener and retail
5	Medium		Skin damage from brushes	Room-cooled to 8°C but rewarmed to ambient at packing	None, loaded at 20°C	**Avg: 12°C** Min: 9°C Max: 20°C	No forced-air, slow warming, then 15-20°C	7-9°C for 12 hrs	High levels at points after transport

Packhouse	Supply chain length*	Harvest impacts	Impacts along packing line	Cooling before packing	Cooling after packing	Transport temperatures	Ripening temperatures	Ripener to retail temps	Internal damage at ripe
6	**Medium**		No damaging impacts	Room-cooled from 30 to 21°C, but packed within 24hrs	10°C within 20hrs	**Avg: 9°C** Min: 7°C Max: 11°C	Slowly increased to 20°C, then forced-air to 5°C	Load 1: 8°C for 24hrs Load 2: 5-10°C for 48hrs	Low-medium levels (10-15%) at all stages
7	Short		No damaging impacts	Forced-air from 27°C to 10°C in 10 hrs	Cooled to 7°C before dispatch	**Avg: 9°C** Min: 5°C Max: 12°C	Forced-air warming to 18-20°C, then forced-air cooling to 5°C		Low levels of at all stages of supply chain
8	Short and medium		Damaging impacts, flesh bruising identified		Room-cooled to 7°C within 30 hrs	Short length: **Avg: 6°C** Min: 5°C Max: 8°C Medium length: **Avg: 12°C** Min: 8°C Max: 15°C	Forced-air warming to 15-20°C, then forced-air cooling to 5°C		Moderate incidence (15%) of rots at all stages of supply chain
9	Medium		Bin tip impacts close to damaging level	Held at 20°C and packed within 24 hrs	5°C within 20 hrs	**Avg: 8°C** Min: 5°C Max: 12°C	Forced-air warming to 15°C-20°C, forced-air cooled to 4°C		High incidence (30-50%) of low level rots at all stages

Packhouse	Supply chain length*	Harvest impacts	Impacts along packing line	Cooling before packing	Cooling after packing	Transport temperatures	Ripening temperatures	Ripener to retail temps	Internal damage at ripe
10	Long	Damaging impacts in cherry picker bags	No damaging impacts	Room-cooled 23°C to 15°C within 20 hrs	12°C at dispatch	Load 1: **Avg: 10°C** Min: 7°C Max: 12°C Load 2: **Avg: 12°C** Min: 7°C Max: 15°C			High incidence (50-100%) of severe rots (>20% flesh affected)
11	Long	Damaging impacts in cherry picker bags	No damaging impacts	Room-cooled from 25°C to 10°C within 25hrs.					
12	Long		No damaging impacts		Forced-air cooled to 5°C	**Avg: 5°C** Min: 4.5°C Max: 6°C			

1.4 Conclusions

Assessment of supply-chain practices and fruit quality across major packhouses in Australia was a useful engagement tool. It provided packhouse managers with data that outlined how their supply chain was performing. These included issues to be resolved and, in some cases, potential improvements in fruit quality that can be made through practice change.

Impacts on fruit at harvest were potentially damaging when picking fruit into full-depth mechanical work platform bags. Halving the bag depth was recommended to reduce that risk. Impacts along most packing lines were well below damaging levels.

Poor temperature management (along with a lack of temperature monitoring) was the major issue identified in the studies. Cooling before packing was usually by room-cooling, which was shown to be slow and non-uniform through the picking bin compared to forced-air cooling.

Fruit was usually only partially cooled before transport, resulting in above-optimal transport temperatures from the start of the trip. Additionally, some truck cooling systems were unable to stabilise temperatures during transport, with the result that a number of loads warmed up on route. Packhouse managers were often unaware of these issues in their transport system, and have been encouraged to address these issues with their transport company and start regular monitoring of transport temperatures.

Ripening with forced-air systems, which is recommended best practice, was not always the case, with fruit left to passively warm and then fluctuate in temperature during ripening.

The limited number of supply chains monitored from ripener to retail indicated a well-managed system, where fruit arrived in stores within a short time, under refrigeration. Further monitoring of that system during high fruit supply periods is required to get an overall idea of its performance.

Fruit quality varied largely between packhouses, and quality issues through the supply chain often indicated a pre- or postharvest practice that needed addressing. Quality monitoring through the supply chain was therefore a useful tool to help supply-chain stakeholders understand the impact of pre- and postharvest practices on fruit quality.



Review of avocado best practice resources

Australian and international



Contents

1. Introduction

In recent years, a range of best-practice training and education materials have been produced for Australian avocado supply-chain members, including printed guides, posters, and stickers, and an online best-practice resource. These materials were designed to assist in addressing fruit-quality issues including maturity, ripeness and internal damage[1].

Despite the availability of such resource materials, fruit damage at retail remains high. Currently, approximately 25% of the avocados on retail sale are damaged. This means that more than 10% of the internal flesh is damaged by either bruising or internal rots. Most of the bruising is occurring at the retail end of the supply chain, while fruit rots develop due to a range of orchard, storage and handling factors.

In discussions with avocado industry stakeholders at the Supply Chain Workshop on 14 March, 2016, it became apparent that there are still some gaps between industry practice and best practice through the supply chain. This suggests that there is room for improving the use of current supply chain education materials, as well as updating content to reflect best practice, particularly among some aspects of cool-chain management and fruit management at retail.

As part of this project, a review was undertaken of all current Australian supply-chain materials (orchard through to retail) to identify areas of improvement – both in terms of content and ease of use. Avocado education materials available from New Zealand, South Africa and the US were also evaluated for content and presentation. Best-practice materials from other fruit industries including mango, banana, pear and grapes were also considered for useful ways of presenting material.

Recommended practices within the Australian avocado resources were compared with that of the New Zealand, South African and US resources as well as best practice based on the review of recent avocado research (Tasks 2&4, AV15010). Some differences and gaps in knowledge were identified between these sources.

Recommendations for new best practice materials at each point in the supply chain were developed, as well as recommendations for improvements in the online best practice resource. This will inform the next phase of the project (Task 7): "to refresh best practice resources for all sectors of the supply chain, from grower to retailer".

[1] Embry J. et al. 2010. Avocado supply chain education materials. Final Report AV08017 Horticulture Australia Ltd.

2. Materials and method

2.1 Collation of resources

Supply chain educational materials were collated from the Australian and international avocado industries, as well as from other fruit industries. Australian supply chain materials were collated from the Avocados Australia online best-practice resource, and included printed and online material (Appendix 1. List of Australian avocado resources). Best practice resources were gathered from New Zealand, South African and US online sources (Appendix 2. List of international avocado resources). Supply- chain practices were discussed in meetings with New Zealand Avocado Industry Council and US avocado industry stakeholders from Calavo, California Avocado Commission, West Pak Avos and Mission Produce. Materials from mango, banana, pear and dried grape industries were collated to get ideas from educational materials used in other industries (Appendix 3. List of resources from other industries).

2.2 Reviews of resources

Detailed reviews were made of Australian resources by stage of the supply chain, including: growing, maturity testing, harvesting, packhouse, transport, wholesale, ripening and retail. Retail resources were assessed by Produce Marketing Australia under AV15011; disease management resources were assessed by plant pathologist Len Tesoriero; while the remaining resources were assessed by AHR staff. First, the reviewers assessed the content of the resources – were the messages about best practice? Second, to determine how usable the resources were, the reviewers assessed how well the information is organised – whether the format, e.g. booklet, poster, online or factsheet is appropriate – as well as the presentation of the information. Finally, the reviewer provided additional comments and ideas for improvements, and ideas from international avocado resources or other fruit industry resources.

The reviews were summarised into key recommendations, which, following consultation with the industry, will be used to guide Task 7 of AV15010: "Refresh best practice resources for all sectors of the supply chain and publish in a format most suitable to supply-chain stakeholders in each sector from grower to retailer".

2.3 Comparison of key practices with research and international sources

While there are numerous best practices that should be followed throughout the avocado supply chain, there are some that have been identified as critical in reducing damaged fruit at retail (Tasks 2 & 4, AV15010). Furthermore, it is important that the practices recommended in the Australian resources follow the up-to-date best practice. Therefore, there was a comparison of what the Australian Best Practice Resources and international resources suggest at those critical points, and what is considered best practice based on the review of recent avocado research (Task 2&4, AV15010.

3. Results

3.1 Australian Best Practice Resource review

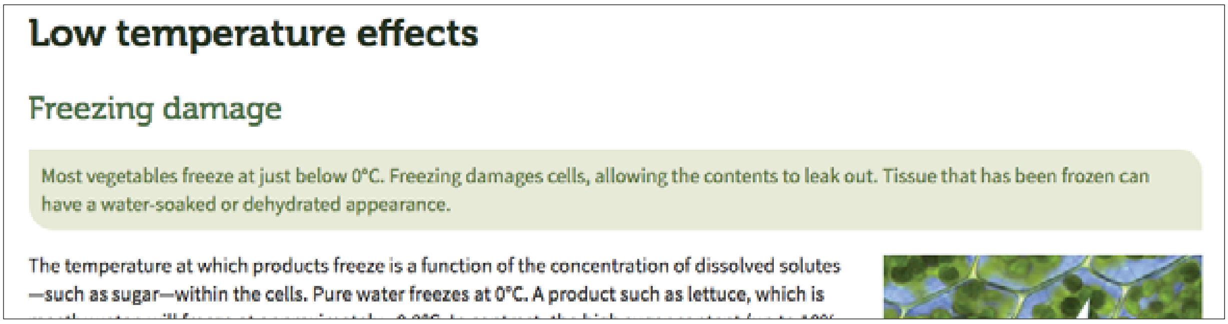
3.1.1 General comments

Content

In general, the online best-practice resource is a good resource with plenty of useful content. However, **some gaps in content have been identified**, and should be filled with new material. The gaps are provided in detail in the sections that follow, but in summary include:

- Growing – Section specifically on preharvest management of fruit diseases
- Maturity testing – details on how to sample a block, recommendation of best method for testing
- Harvesting – A separate module on harvesting with more detailed content
- Packhouse – More detail required, particularly on cooling, temperature management and postharvest treatments for rots
- Transport – effect of breaks in the cool chain
- Wholesale – Stock rotation and the importance of fruit age
- Ripening – Consistent stages of ripeness across the industry, instructional video on ripening
- Retail – Material needs to be more relevant to retail staff

While the content is thorough, it is often **difficult to find what the key message is**. Most readers will be time-poor, and are likely to skim through the material, potentially missing key messages. Therefore, key message boxes should be added to all sections of the online resource. For example, on a vegetable postharvest management website (www.postharvest.org.au), key messages are highlighted prior to discussion in detail:


Low temperature effects

Freezing damage

Most vegetables freeze at just below 0°C. Freezing damages cells, allowing the contents to leak out. Tissue that has been frozen can have a water-soaked or dehydrated appearance.

The temperature at which products freeze is a function of the concentration of dissolved solutes —such as sugar—within the cells. Pure water freezes at 0°C. A product such as lettuce, which is

Time and temperature: From a cool chain perspective, **time** and **temperature** are two critical factors that influence fruit quality. In general, these factors require more attention and detail in the online and printed resources. There is also a need to produce a **cool chain management guide** from harvest to retail. Many of the avocado businesses are partly or fully integrated – from growing to retail – so a single guide like this would be useful.

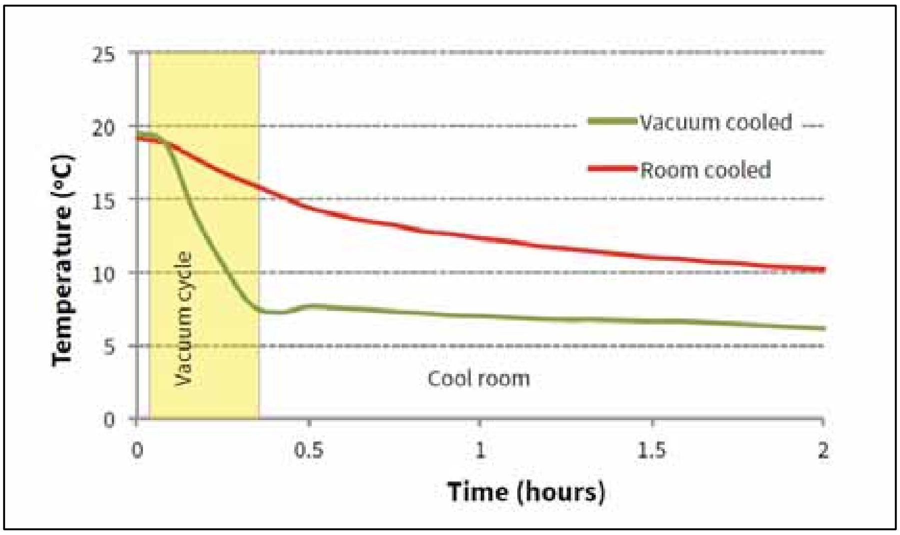
In some cases, messages may be simplified throughout the resources. For example:

- "Do not drop fruit" instead of the current message: "Do not drop more than 30cm"

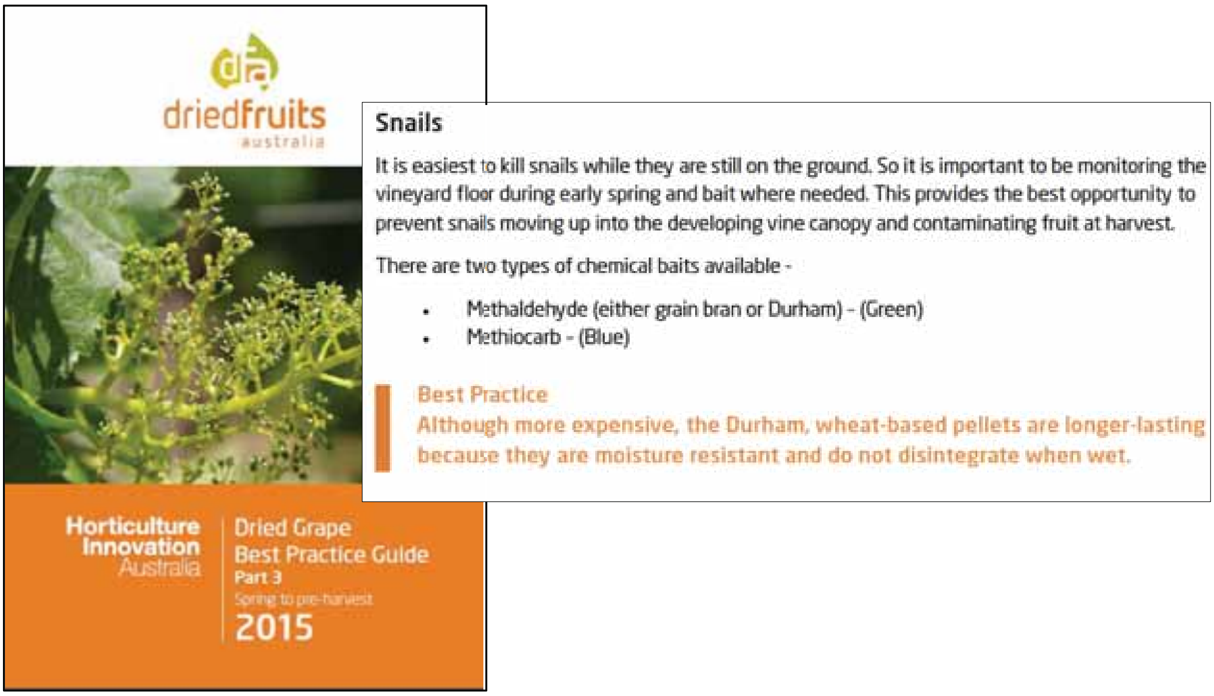
Describing best practice

Examples from other industries were assessed for how to describe and demonstrate the importance of best practice in a clear and practical way.

The Australian Postharvest Management of Vegetables Guide includes data that helps demonstrate why best practice should be followed. For example, in the cooling section, product data is provided that illustrates why vacuum cooling should be used over room cooling. Similar data could be generated for temperature management in the avocado cool chain.



The Australian Dried Grapes Best Practice Manual follows a useful format for illustrating best practice. Within each section, they first outline the issue that could arise if best practice is not followed, and then clearly highlight the best practice for eliminating the issue. A similar format could be used in any of the avocado best practice manuals.



Organisation of information

The **modules need to be re-ordered** in the online resource, so they flow like the processes of the supply chain. At present, ripening comes first and growing comes last.

The subheadings within a module need to be reordered so they flow in logical order of the process – e.g. in the packhouse module, grading comes first, while maturity is at the end.

The retail module could be moved to the professionals section of www.avocado.org.au so that retailers can find the material more easily and do not need to log in.

Usability

The online content needs to have a more intuitive interface where it is clear which piece of information comes next, and where to find it because currently once you click on a module the subheadings within the modules are not clearly visible. See www.postharvest.org.au below, which has an interface that is more intuitive. It would be useful to have a similar "in this section" and "related pages" at the bottom of each page. That way, when you read through to the bottom of a page, you don't have to scroll back to the top to find the link to the next section.

Other issues with the usability and presentation include:

- Hyperlinks to other sections/printable materials are missing in some places
- Video links, and links to printed resources are difficult to find and should be posted as an image and should be easily found
- While the background green colour of the resources relates well to avocado it is hard to read and should be white

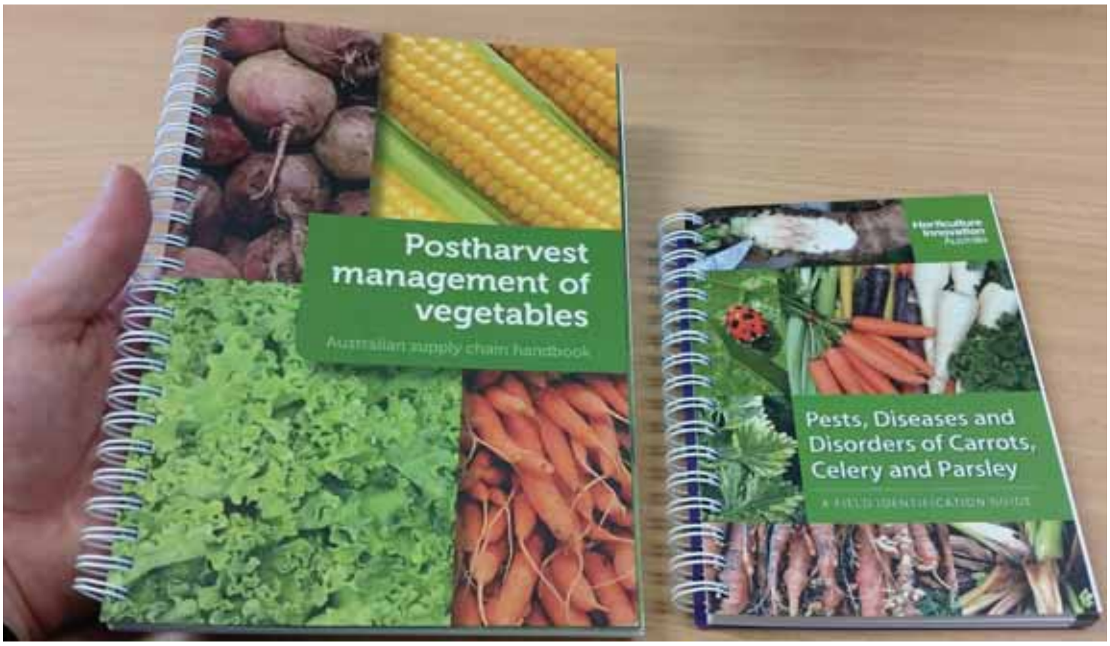
The **course system** at the end of each module is a useful way of reinforcing and checking understanding of content. However, the course should be more interactive, with more videos and/or links to break up the text. Less text should be used, and to do this, the course could have a narrated presentation. Key points should be outlined in a box at the end of each module.

Ideas from other resources

Most other online best-practice resources are set out in a PDF/book-style document. These include:

- New Zealand Avocado Best Practice Resource
- Australian Banana Best Management Practices
- USA Mango Postharvest Best Practice Manual
- Australian Dried Grape Best Practice Manual
- USA Pears – handling manual

It is likely that a **single best-practice document for each sector** of the supply would also be useful in the Australian avocado industry. While this format is less interactive compared to an online resource, it is printable and allows the user to look through a complete module without potentially missing valuable information, and without getting sidetracked by other links. A complete document like this can also be printed as a small guide and kept in the car, packhouse or office, etc. The ute guide and handbook format have proven popular within the Australian vegetable Industry, including a postharvest management of vegetables handbook and pest and disease ute guides.



3.1.2 Growing module

Resource: Online best practice resource – growing module

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
General comments	• Great content, and in excellent detail • Some sections are not directly related to growers and should be moved elsewhere • Needs a section specifically on preharvest fruit-disease management	• Current modules should be organised better by topic (see outline in comments below) • Each module should have a full document containing all the information from within that module • In some cases the acknowledgements are presented first – key introductory points should be made first, and then acknowledgements	• A printed growing guide would be a great way to display the material – no such guide exists • Large amounts of detail in the resource could be summarised in a self-assessment tool (see comments below)	• Large amounts of text need to be broken up into smaller sections • Critical practices/key points should be highlighted in a box at the top of each section • References to further information or materials should be more obvious by clearly highlighting hyperlinks or snapshots of videos
Anthracnose	Thorough content, though trade names should be provided for fungicide spray recommendations. Contains information on disease control and harvesting precautions that should be moved to modules specifically on those topics.	Move to a module covering disease.	A factsheet would be a useful format for this disease.	A diagram of management strategies would be a useful summary.
Biosecurity	The Orchard Biosecurity Manual is an excellent resource for this section, however more attention should be drawn to it in the text on the online resource (or an image of the manual could be shown).	Well organised.	Manual is an appropriate form.	Excellent.
Canopy management	Thorough content, with plenty of detail.	Acknowledgements should be moved to the end, and instead 'reasons for canopy management' should be listed first.	Each of the 6 pruning options could be made into factsheets.	Require better use of subheadings and spacing between information in each of the 6 pruning options – it is not immediately obvious where a new subheading starts.

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
Crop cycle calendars	Great resource, but consider addition of fungicide requirements for stem end rots.	Suitable.	Best as a printed poster.	Great.
Harvesting	Thorough content, but requires a summary of key practices that need to be followed.	Suitable.	Factsheet could be useful.	Requires emphasis of key points with 'key point boxes' or highlighted text.
Irregular and alternate bearing	Suitable content.	Definitions and occurrence should be moved to the first page that comes up when the subject is clicked on.	Factsheet could be useful.	
Irrigation	Great content, though more photos and diagrams would be useful – e.g. basic design requirements section.	Needs improvement – the module is currently split into 15 different sections. The module should instead only be split into: introduction; calculating water demand; measuring soil moisture; irrigation system design and methods; and efficient water use.	Requires a manual or chapter within the growing manual.	
Mulching	Generally very thorough, though could provide recommendations on time of year to apply (or refer to crop cycle calendar).	Suitable.	Factsheet could be useful.	More images required.
Nutrition	Thorough content.	Suitable.	A general nutrition factsheet (introduction style) would be useful.	
Other diseases	Include anthracnose and phytophthora in here. Include a reference to the problem solver field guide.	Separate into plant and fruit diseases.	Excellent field guide already available.	
Other insect pests	Suitable. Could include a table of prevalence by region.	Suitable.		
Pollination	Suitable.	Suitable.	Factsheet style could be useful.	
Phytophthora root rot	Thorough content.	Include under diseases.	Factsheet could be useful.	Link to video needs to be made clearer – a snapshot of the video could be provided to click on.
Qualicado	Move to outside of the 'growing' section.			

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
Rootstock selection	Despite avocado production in Australia covering a diverse range of climates, there should be some sort of recommendations made of rootstocks for regions/orchard situation (e.g. poorly drained soil, saline soil, cool conditions etc.) – presented in a large table.	Move to 'orchard establishment' section.	Factsheet style.	Summarise in tables.
Selecting varieties and		Move to 'orchard establishment' section.		
Site selection		Move to 'orchard establishment' section.	Factsheet could be useful.	
Soil health	Suitable	Suitable.	Factsheet could be useful.	
South American orchard visits		Move to outside of the 'growing' module.		
Spotting bug	Include reference to new 'Fruit Spotting Bug Management Guide'.	Suitable. Move to 'insect pests' section.	Refer to new guide.	
Study group minutes		Move to outside of the 'growing' module.		

Ideas from other resources

The **Australian Banana Best Management Practices Guide** presents a grower-self assessment tool at the start of the resource. A tool like this in the avocado online resource would provide growers with a rapid way of determining how their current practices compare to industry best practice. Where improvements are required, links could be provided to the relevant information that explains those practices in detail.

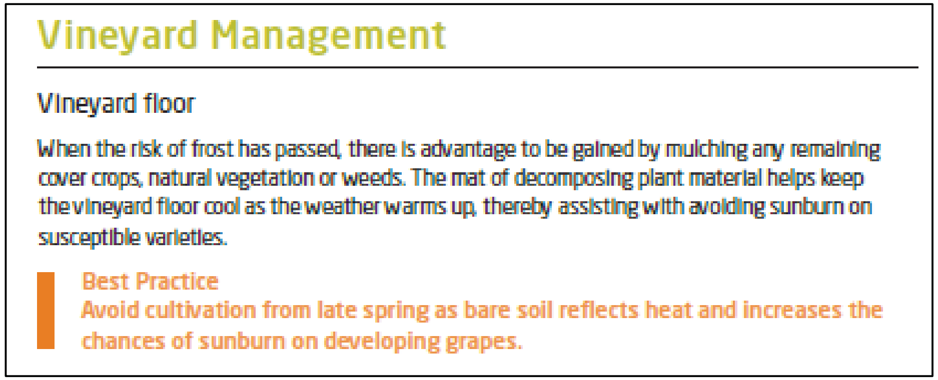
Soil erosion

1. Ground cover

❍	Living ground cover is encouraged in areas such as the inter-row space and headlands, excluding major roadways.	[Best]
❍	Living or dead, at least 60% ground cover is encouraged in areas such as the inter-row space and headlands. This includes mulching banana plant material in the inter-row space. Major roadways are excluded.	[Okay]
❍	Areas such as inter-rows and headlands are sprayed bare.	[Improve]
❍	N/A	

The Qualicado Grower Pre-Harvest Assessment could be adapted for use online, in a similar format to that of the banana guide. A summary could be generated consisting of: major improvements needed; room for some changes; best practice already implemented. Where improvements are required, hyperlinks could be provided to the appropriate online module with details of best practice that should be implemented.

The **Australian Dried Grapes Best Practice Manual** provides an explanation on each pre-harvest practice, including effects of not following the practice. Below the explanation of each issue is a 'best practice' paragraph outlining what the industry best practice is, and why it was chosen as best practice. This would be a useful way to present best practice in an avocado growing manual.


Vineyard Management

Vineyard floor

When the risk of frost has passed, there is advantage to be gained by mulching any remaining cover crops, natural vegetation or weeds. The mat of decomposing plant material helps keep the vineyard floor cool as the weather warms up, thereby assisting with avoiding sunburn on susceptible varieties.

Best Practice
Avoid cultivation from late spring as bare soil reflects heat and increases the chances of sunburn on developing grapes.

Proposed outline for growing resource modules by topic

The content in the online growing module needs to be structured in a more logical way. The following is a new outline that could be used:

- Orchard establishment
    - Training young trees
    - Site selection
    - Selecting varieties and pollinisers
    - Rootstock selection
- Orchard practices
    - Crop cycle calendars
    - Irrigation
    - Nutrition
    - Mulching
    - Canopy management
    - Pollination
    - Harvesting
- Soil health
- Irregular and alternate bearing
- Pest and disease management
    - Diseases
        - Preharvest
            - Phytophthora root rot
            - Other diseases
        - Fruit rot management
            - Anthracnose
            - Stem end rot
    - Insect pests
        - Spotting bug
        - Other insect pests
- Biosecurity

Resource: The Avocado Problem Solver Field Guide

Section	**Content evaluation**	**Organisation of info**	**Format (e.g. booklet, poster, factsheet etc.)**	**Presentation**
General comments	• The field guide is an excellent resource that is thorough in content • The guide has excellent photos and descriptions of disorders	• Well organised • Separating the sections into identification and then treatment is a great idea, as is separation of issues by plant part	• Handbook is a good size for use in the field/ute	• Excellent photos • Great separation of handbook sections

3.1.3 Maturity testing module

Resource: Online best practice resource – maturity section

Section	**Content evaluation**	**Organisation of info**	**Format (e.g. booklet, poster, factsheet etc.)**	**Presentation**
General comments	• Most of the required content is in there, but needs more about how to select a sample to test	• Difficult to find the important information quickly	• Currently in an online PDF, but could be improved in a factsheet style • Could be incorporated in both the growing and harvesting manuals	• Too wordy, and not divided up by enough subheadings • Use a summary table including things like minimum DM standards, tests used, etc.
Deciding when to harvest	Include some images of mature vs. immature fruit	Needs subheadings to divide up information		
Dry matter test	Make a recommendation of the easiest test (grated vs. coring) and the easiest way to dry the samples			
Sample preparation	Needs more information about how to select 10 fruit for testing (see notes from NZ resource below)			

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
Calculate percentage dry matter	The note at the end on 'DM standards for over maturity' should be moved to the earlier section on 'deciding when to harvest'		Could contain an online calculator that just requires weight values to be entered	
Videos	The video follows the content of the online resource, and provides enough information if the online resource is updated	Link to videos is too far down the page and not highlighted – show a snapshot link to the videos		

Ideas from other resources

The **New Zealand avocado maturity testing procedure** recommends the following which could also be incorporated into the Australian resource:

- Reminder to keep records of fruit maturity test results
- Useful detail on how to sample fruit for testing, and maturity variation within the orchard that should be considered
- Instructions for collecting fruit

The **South African Harvesting and Packing Guide** recommends fruit mineral analysis prior to and at the time of maturity testing. Nitrogen and calcium levels are measured, which can either be used to try and rectify issues, or allocate fruit based on it's nutritional robustness (high Ca and lower N usually indicates fruit will store better).

3.1.4 Harvesting module

Resources: Online best practice resource, posters and video

Resource	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
General comments	• A more detailed resource is required and should be in a module of its own • Needs to emphasise and explain why fruit need to be cooled ASAP after harvest • Mixed messages on dropping fruit and picking in the rain need to be removed	• Suggest a more logical order that follow the harvesting process	• A harvesting manual could be presented in a ute guide format for growers • Keep the posters and video for pickers	• Picking guides could be translated into a number of languages
Avocado harvesting: Growers and managers	• Include minimum maturity requirements • Remove mention of 'dropping more than 30cm' – replace with: 'discard dropped avocados' • Pickers – include something on snipping greenskins vs. plucking Hass • Packhouse assessments and library tray system should not be included here, rather in the packhouse guide • Needs some information on the importance of cooling fruit ASAP after harvest	• Use of Amistar fungicide should come under pre-harvest • The subheadings on the poster need to be put in a more logical order – i.e. mature, pre-harvest, harvest, pickers, equipment, field bins, post-harvest	Keep as a simple poster	Could be presented in a flow diagram, or have arrows moving through the process
Avocado harvesting: pickers	• When it rains – change from 'do I pick?' to 'DO NOT pick' • Remove: 'Dropping over 30cm', and just write 'Dropped me? Throw me out!'	Put some arrows between boxes to show order of instructions	Keep as a poster	It would be great if it was translated into a number of different languages that represent the commonly

Resource	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
				spoken backpacker languages
Harvesting video	• Nothing on the importance of getting fruit to the packhouse/coolroom quickly	Great	Keep as a video to go with the poster	Needs to be front and centre of the online resource – but it is currently buried in the text

Ideas from other resources

The **QDAF website; South African Harvesting and Packing Guide; and California Avocado Commission 'Growing for Quality' manual** have some useful information that could be added to the harvesting module, including:

- Temperatures during which to avoid harvest
- Ensure damaged fruit are not put in the picking bin
- Maintain access roads
- Issue of fruit water loss
- What happens if fruit are held warm for too long after harvest
- What happens if fruit are handled when wet
- Preventing lenticel damage

The **California Avocado Commission 'Growing for Quality' manual** gives some good examples of what can happen if best practice is not followed, and also highlights key points in bold text or key point boxes:

3. **Fruit transpire and can lose significant quantities of water after harvesting,** with a consequent loss of quality. Water loss can also aggravate the symptoms of mechanical damage and cold or warm temperature injury.

4. **Fruit are very sensitive to temperature.** Fruit picked at higher temperatures (> 90° F) rather than at lower temperatures (< 70° F) will:

   - Lose up to 10 % more weight
   - Respire at a much higher rate and accumulate heat in bins
   - Take significantly longer to cool

   At lower the temperatures, rates of fruit respiration are lower. However, excessively low temperatures can also induce chilling injury.

Two factors which greatly increase the risk of fruit developing commercially unacceptable levels of rots are:

- **Handling wet fruit at harvest and**
- **Holding fruit too long after harvest.**

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Fruit harvested for up to 2 weeks after 2-3 days of significant rainfall is thought to carry a higher risk of fungal infection and should be handled accordingly.

3.1.5 Packhouse module

Resources: Online best practice resource and posters

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
General comments	More detail required on: • Precooling – timing, methods, importance of cooling • Issue of water loss before cooling • Temperature management after cooling • Use of postharvest fungicides	• Emphasis required on key points such as precooling and storage • Information should be organised around the steps fruit moves through the packhouse	• Poster format is useful as a reminder and summary • Booklet guide is required for inclusion of more detail – this should be part of the new cool chain guide	• Use photos and graphs/tables in the guide

Maturity	Good – keep as is			
Precooling and storage	Needs more detail on precooling – e.g. if not precooled, then how quickly should fruit be packed and cooled? Temperature to cool to? What method is best? Needs more detail on keeping fruit cool – e.g. limit fruit time in packing shed. Needs detail on use of fungicides.	These are some of the most critical parts of the cool chain, and need to be emphasised more.		
Be Gentle	Should include how to properly stack a pallet, with interlocking strips and straps around the outside.		Poster with images.	
Ripeness guide	Unsure that this should be included in the packhouse poster – if the packhouse is also ripening fruit, then they can just use a ripening poster.		Could be included in the guide, but unnecessary on the poster.	

Ideas from other resources

The **South African Avocado Packing Guide** has some great information, including:

- How to prevent lenticel damage on the packing line
- Use of waxing on fruit
- Postharvest stem dip with fungicides
- Provides reasons that cooling is required
- Provides a summary of key factors in the cool chain that contribute to fruit quality

3.1.6 Transport module

Resources: Online best practice resource, booklet and posters

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
General comments	• Not all of the content is relevant to a transporter – e.g. stacking of boxes • Should emphasise two key points: to maintain the cold chain and minimise movement in transport • How to transport ripe avocados is missing (sometimes go interstate)	• Well organised – the critical information is put first	• Small booklet is good, but put updated info into the new cool chain guide • A quick YouTube video may be useful for drivers to watch on their smartphones	• Colours need changing to be more easily read • Some photos could be larger
1. Importance of maintaining the cool chain	Would benefit from examples of how quickly fruit can warm up when cool chain is broken and the effects on the storage life of the fruit			
2 How to handle avocados – temperature	Change this section to "temperature management" Include the use of temp loggers, with images and costs			
2.2 Air flow	Figures are great, but too much text		Most easily shown in a video	
3. Stacking and securing the load	Most of this is more relevant to the packhouse. Just include importance of strapping pallets, not stacking on top of each other, max stack heights and securing pallet load			
4. Compatibility of avocados with other produce	Good – keep this section		Show it in a table with images of compatible fruit/veg	

Ideas from other resources

The **South African Harvesting and Picking Guide** includes details on truck and container refrigeration requirements and settings.

3.1.7 Wholesale module

Resources: Online best practice resource and posters

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
General comments	Needs to include: • Fruit age management • Temperature measurement • Emphasis on maintaining the cool chain • Checking fruit condition in storage	• Laid out in a logical order	• Posters are good for wholesalers • But also present in the cool chain guide	• Well presented, just change the background colour to make it easier to read • Ripeness chart could be made larger
'Start 'em right'	Good, but also include something on checking for pick/pack date on packaging – if nothing, then ask grower/packhouse			
'Handle 'em right'	Need to include ripening temperature in this section			
'Treat 'em right'	Mixed message in telling people they can drop avocados – just say 'do not drop fruit'			
Ripeness chart	Lacks any mention of fruit age (time from picking)			

3.1.8 Ripening module

Resources: Online best practice resource and ripening manual

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
General comments	• Plenty of useful content, but could reduce wordiness • Emphasise the importance of consistently ripe fruit • Emphasise the need to ripen oldest fruit first • Could include a section on how to hold fruit when the buyer reduces/increase orders • Need to address the 6 stages of ripeness (other Australian resources list 5)	• Info could be better organised to highlight the critical information • Suggest having highlighted key points/messages on each page	• Keep the manual, but make a 5-minute instructional video on the process for new ripeners to watch • Poster of key points – e.g. temperatures, firmness measurement, storage after ripening, growing regions through the year	• Font needs changing to be more easily read • Page colour needs to be made white in order for images and text to be easily seen • Decision charts are good – just need to make them more readable
Steps in ripening	Keep			
Receival assessment	Also include the need to request information from the supplier – e.g. potential issues with fruit due to weather, dry matter, etc. (ripener can prioritise fruit)	Make it instructional – e.g. Step 1, Step 2, etc.	Provide a downloadable/photocopy template form to fill in/use on i-Pad/tablet	Could be displayed as a graphic
Ripening conditions	All useful content, though some repetition.		Could be added to a poster to put in the ripening room or near the room controls	Turn page 3 into a table?
Time to reach required ripeness stage	Need to make content in the table clearer – are these cumulative days? Mid-season Hass should only take 3-4 days to ripen – depends on days from harvest!			
How long to store (and options)	Great decision tree – keep this		Could perhaps be part of the online decision tree?	Different options need to be made easier to follow through – colours will show

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
	Should also emphasise that the key message is: 'Oldest fruit should be ripened first'			up better on white background
Storage after ripening	Good, but needs to distinguish if these storage times are at the ripening facility or include time at the retailer DC?		Add this to the poster	
Ethylene	Include something about why ethylene is needed	Move text from bottom of the page to the relevant system already listed		
Venting	OK, but too wordy	Highlight the key point that CO_2 build-up will inhibit ripening!		
Monitoring	Temp – how much higher should pulp be than air? Reduce wordiness Suggest to check ripening fruit twice daily rather than only once (that way people will do once as a minimum)			Put all info into a table?
Cooling	Should emphasise that forced-air should always be used! Include where best to check if fruit are cooled			
Operating storage room	Good			
Problem solver	Great – keep this			
Questions	Almost all of the questions are already answered in the main guide – is there a need for repetition? Perhaps instead refer back to relevant section			
Assessing ripeness	Good – keep			Include pictures of different instruments
Harvesting periods	Great, keep this		Put up a poster so that ripeners can track where they are at	
Contacts	Good – keep			

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
Ripeness chart	Should be consistent industry wide – e.g. Coles/Woolworths charts list 5 stages Needs to also include a description of each ripeness stage – e.g. hard – very firm, no give; rubbery – very slight give in fruit. Perhaps useful to include purpose of use at each stage – e.g. firm ripe – sliceable; soft ripe – guacamole		Good to keep as a poster	

Consistent stages of ripeness:

The Avocados Australia ripeness guide contains 6 stages, whereas Woolworths only have 5 stages on their poster. There needs to be a consistent number and description of ripeness stages across the industry. The **California Avocado Commission** presents an effective illustration for the stages of ripeness in a poster that could be adapted for use in Australia:

Ideas from other resources

The **New Zealand Avocado Industry Council Ripening Protocol** details the process step-by-step, in an instructional summary:

THE TECHNIQUE

Steps in Controlled Ripening:

1- Place green mature avocados in the ripening room and cool or warm fruit to 16 to 20°C within 8 – 12 hours.
2- Trickle ethylene into the room at 10 to 15 ppm for two days (48 hours)
3- After 48 hours, remove fruit from the influence of ethylene by venting the room with circulating air or placing the fruit into an auxiliary room. Continue to store them at 16 to 20°C until they are 'sprung' (i.e. easily detectable softening when squeezed, which normally occurs between 8 and 12 hours). Avocados will start to soften and will be sprung 1 to 2 days after removal from ethylene.

4- Once avocados have reached the 'sprung' stage they can be stored at 2 to 4°C for 7 to 14 days to slow down further ripening. If left at 16 to 20°C or above, they will take 1 to 3 days to advance to the eating ripe stage from the sprung stage.

3.1.9 Retail module

Resources: Online best practice resource and retail manual

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
General comments	• The 24-page hard copy manual has limited information directly relevant to retail staff • Some content on Handling, Display, Customer Help and Frequently Asked Questions are useful • Brief "Introduction/How to Use" section at the front would have been appropriate • Should emphasise the importance of maintaining the cool chain	• Retail-relevant information should be up front, not in the back half of the publication • Information should flow in the order of processes followed by retail staff • "Best Practice" photo or drawing examples would have been useful to support relevant ideas/text	• This manual is generic for all retailers. Needs to be customised for major retailers to fit their policies and procedures • Multi-faceted format would be more effective, depending on each major retail group e.g. videos, work books, posters, back-room charts, apps, etc., supported by consumer information (POS –like Coles colour guide – and leaflets)	• Fewer words and more use of images, cartoons, drawings, etc. • Font needs changing to be more easily read • Page colour needs to be made white in order for images and text to be easily seen
Retailer Ready Reference Guidelines	Describes generic "What to do", but lacking in "How to do it". Having "Additional Information" up-front is good, although it could be more prominent. Background information only			
1. Industry Overview	Irrelevant, apart from possibly Production regions.			
2. Avocado Quality Issues	External Quality – describes issues irrelevant to retail staff – orchard, pack-house, ripening or storage issues. Internal quality – some content may be useful background for customer communication by staff.			Take only the information that is relevant and where staff can have an impact (good and bad).
3. Reduce Avocado Wastage	Good content and graphics.	Re-order so there is a flow like the product flows along the retail chain.	Incorporate information in relevant formats.	Needs fewer words and more imagery.

Section	Content evaluation	Organisation of info	Format (e.g. booklet, poster, factsheet etc.)	Presentation
4. Available Support Mechanisms	Good idea to set out the totality of resources available.	Would be better if it showed how the resources all link together.	Hard copy factsheet and/or printing from electronic availability.	Use a flow chart to better show the resources available.
Frequently Asked Questions	Some useful content, but significant sections are irrelevant to retail staff.	Could be better organised, i.e. in order of questions expected from consumers.	Incorporate a brief section in a hard copy guide and on-line.	Fewer words required.

Ideas from other resources

Retail training programs across a number of different industries have been sourced and assessed for useful components. These include:

- US Fresh Fruit Basic Training Program
- USA Pears: Pear Marketing and Merchandising Training Program
- Albert's Organic Education Center
- PMA Essentials
- 2014 Produce Market guide
- Retail Fruit and Vegetable Marketing Guide
- NZ avocado retail toolkit

3.2 Comparison of key practices with research and international sources

The following table provides a comparison of what the Australian Best Practice Resources and international resources suggest at critical best practice points, and what is considered best practice based on the review of recent avocado research (Tasks 2&4, AV15010). Text in red indicates gaps in knowledge that need addressing. The raised hand indicates major differences between Australian best-practice recommendations, and those recommended internationally or in research.

Practice	Best practice[2]	Australia[3]	New Zealand[4]	USA[5]	South Africa[6]
Growing					
• Fungicide program	Apply fungicide at flowering? Then at least 5 coppers through the season	Regular copper from fruit set and strategic azoxystrobin	8 coppers/season		
• Rootstocks	Benefits from rootstocks can be highly site and climate specific	Choose roostocks that elevate fruit Ca levels – e.g. Velvick (not Duke 6)	Zutano (seedling) most common – move towards Dusa, Bounty (clonal)		
• Ca:N levels in fruit	Higher Ca, not too high N (though difficult to increase Ca in fruit)	High Ca, not too high N		Achieve high Ca, avoid high N	Measured 8 weeks prior to harvest in fruit
• Soil and leaf nutrient test		Leaf annually, soil every 2nd or 3rd year	Annually		

[2] Based on AV15010 Task 2 – Avocado postharvest research review
[3] Based on AAL supply chain education materials
[4] Based on meetings with Colin Partridge (Technical Manager, Team Avocado), and Glenys Parton (Industry Systems Manager, NZ Avocado Industry Council)
[5] Mission produce practices – based on meetings with James Donovan (Senior Vice President, Global Sourcing and Logistics) and Denise Junqueiro (Customer Marketing Manager)
[6] South African Avocado Growers' Association best practice resources

Practice	Best practice[2]	Australia[3]	New Zealand[4]	USA[5]	South Africa[6]
Harvesting					
• Minimum dry matter %	Hass – 25% based on consumer preferance studies	Hass – 23% Shepard -21%	24% Hass		23% Hass
• Soil moisture leading up to harvest	Try and keep consistent	Not mentioned			
• Maximum dry matter %	Increased levels of rots at advanced maturity	No max. standard			
• Clip vs. snap	Clip in wet areas, snap in dry	Snap	Clip	Clip. Although snapping considered during part of the season in certain areas.	Clip
• Air temperature while picking	No limits so long as fruit are cooled within 6hrs	No limits	Not an issue	Ideally pick <32ºC, only pick shaded fruit when >32ºC	
• Picking in rain	Wait until fruit are dry. Delay 48hrs after heavy rain.	Wait until fruit are dry. Wait 48hrs after heavy rain	Sometimes	No	No, or when wet with dew
• Cover bins?	Yes, and take to packhouse within 2 hours of picking	Yes	Yes		80% shade cloth
• Fungicide at time of harvest	Gap	No	No		Dip freshly cut stem in Biocoat®/Prochloraz solution

Practice	Best practice[2]	Australia[3]	New Zealand[4]	USA[5]	South Africa[6]
• Dropping of fruit 	Try and avoid dropping at all	No more than 30cm			
Packhouse					
• Postharvest fungicides	Gap – Prochloraz effects are inconsistent. Thyme oil promising	Not mentioned in resources, but Prochloraz used	None – market issues with Prochloraz		
• Timing of fungicide 	<24hrs after harvest	NA	NA		At harvest
• Time from harvest to packing/precooling	Pick and pack/cool to 5°C within 24hrs	Within 6hrs of harvest	Pick to pack within 48hrs	8hrs ideally	2hrs ideal 12hrs max
• Precooling?	Forced-air with flow rate of 0.5–2.0 L.kg^{-1}.sec^{-1} or hydrocooling	Forced-air recommended 5-7°C	None – room cool after packing	Yes, hydrocooling to 5°C with chlorine	Recommend forced air or hydrocooling
• Cooling after packing	Forced-air if not precooled	Forced-air if not precooled	Room cooling to 5.5°C – keep records	Maintain 5°C	
• Waxing 	Gap Can reduce weight loss and increase shelf life	No	No		Yes – within 48hrs of harvest (Avoshine® and Carnauba wax)
Transport					
• Precool truck before loading	Yes	Yes	Yes		Yes
• Temperature control – delivery vs return air	Minimise difference between delivery air and setpoint	5-7 °C			Use delivery air 5.5°C
• Use temp loggers	In all loads	Yes	Yes		

Practice	Best practice[2]	Australia[3]	New Zealand[4]	USA[5]	South Africa[6]
• Use sealed docks/minimise heat exposure	Minimise heat exposure	Max 30 mins out of cooling			
• Airflow	Rates – 0.2-0.6 $m.sec^{-1}$ over cooled fruit (reduced waterloss)	Avoid tautliners, ensure good airflow			
• Maintain coolchain	Breaks for as little as 5hrs can increase rots				
Wholesaler					
• Maintain coolchain	5°C	Suggests 5°C – but does not emphasise maintaining coolchain			
• Stock rotation	By time from harvest	No recommendation	By time from harvest		
Ripener					
• Temperature for ripening	Ripen at 15°C if risk of rots, otherwise 16-20°C. Raise temp of all fruit uniformly prior to C_2H_4 release	18-20 °C for <26% dry matter 16-18 °C for >26% dry matter	16-18°C - usually 14°C – if rots	15.5-20 °C	
• Temperature for storage of ripe fruit	Do not cool fruit during the climacteric stage	Do not store fruit at stages 2-3 below 16°C Ripe Hass: 5°C Ripe Shepard: 7°C			
• Consistent ripeness metrics	International Avocado Quality	No – Best practice resource list 6 stages,		5 stages – California Avocado Commission	

Practice	Best practice[2]	Australia[3]	New Zealand[4]	USA[5]	South Africa[6]
	Manual suggests Stages 0-7	whereas Coles/Woolworths list 5			
• Condition to ripen to	Best storage at 'rubbery-sprung' (Stage 2) to 'Sprung softening' (Stage 3)	Varies between retailers from breaking to ready-to-eat		Stage 3-4 (breaking to firm-ripe) – ready in 1-2 days. Calavo use acoustic firmness sensors.	
• Stock management	By time from harvest or fruit firmness	By time from harvest or fruit firmness	By time from harvest or fruit firmness		
• Max. fruit age	Max 21 days in coolstorage	Up to 21 days (depending on growing region)	30 days		28 days
Retail					
• Max. storage time once ripened	5 days max. for 'sprung-softening' (Stage 3) fruit at 5°C	Hass: 5-7 days Shepard: 5 days		Up to 7 days	
• Storage temperature (ripe)	5 °C	Not provided in retailer manual	1-2 °C	2-4.5 °C	

4. Recommendations

4.1 General recommendations

1. Make the online best-practice resource more usable by:
    a. Making the website interface more intuitive
    b. Reducing large amounts of text by use of subheadings
    c. Changing the background colour to white
    d. Including key message boxes at the start of paragraphs
    e. Reordering content so that it flows like the processes being described
    f. Adding links to the following components of the module at the bottom of each page so it is clear where to go next
    g. Ensuring hyperlinks to other sections, printable materials, or videos are clearly visible
    h. Updating the course system at the end of modules to a more modern format that is more interactive with videos and photos
    i. Creating a self-assessment tool within each module as a quick way for the supply chain stakeholder to identify improvements they can make

2. Develop a cross-supply chain "Cool chain management guide". This should focus on improving fruit quality, and in particular:
    a. Correct management of temperature at harvest, cooling, packing, transport and ripening
    b. Correct management of fruit age
    c. Use of temperature logging – both fruit pulp and air
    d. Outlining the effects on fruit quality and storage life if the cool chain is broken
    e. Outlining the effects on fruit quality and storage life if fruit is not cooled quickly enough
    f. Comparing cooling rates of air and forced-air cooling

3. Keep the messages simple – e.g. don't drop fruit, instead of don't drop more than 30cm

4. Make the information in the best practice guides more real by sourcing or developing trial data that demonstrates the gains (physical and financial) made by following a particular best practice – e.g. temperature logger data that compares fruit pulp temperature of room-cooled fruit and forced-air cooled fruit.

5. Consult with industry about gaps between Australian best-practice recommendations and those from international avocado industries and the review of recent research (Section 3.2). Industry experts and supply-chain members should be consulted as to whether changes should be made to the Australian Best Practice Resource based on the gaps identified.

4.2 Recommendations by supply chain sector

Printed or PDF documents of a complete best practice guide for each sector of the supply chain should be produced. This would be based on the material in the online best practice resource once it has been updated.

4.2.1 Growing
Develop a single growing guide that includes all the information from the online best-practice resource. Note that pest and diseases are covered already in the problem solver guide.

A particular section of the guide should be on preharvest management of postharvest fruit disease.

4.2.2 Maturity testing
Create a short guide/factsheet on maturity testing that can be used by either growers or packhouses.

4.2.3 Harvesting
A more detailed resource is required and should emphasise and explain the importance of cooling fruit ASAP after harvest. This should be part of the new cool chain guide, and also updated on the online resource.

4.2.4 Packhouse
A more detailed resource is required, focusing on cool-chain management and postharvest disease management. This should be part of the new cool-chain guide, and also updated on the online resource.

4.2.5 Transport
Keep the existing transport guide, but include transport in the new cool-chain guide.

4.2.6 Wholesale
Combine with ripening.

4.2.7 Ripening
Make some minor changes to the existing material in the manual. Produce an instructional video on ripening for new ripeners to watch. Emphasise the importance of stock management by fruit age, and temperature management.

Include ripening/wholesale in the new cool chain guide.

Ensure consistent stages of ripeness are being used across the industry.

4.2.8 Retail
Create a retail module on the "professionals" section of www.avocado.org.au based on the material produced in the revised manual.

The manual needs significant work to ensure it is relevant to retail staff and can be quickly and easily understood by them. PMA will work on this manual as part of AV15011.

5. Conclusion

The Australian avocado best-practice materials are great resources with plenty of useful content. Most of the necessary information is available from the resources but the ease of use limits the ability of a user to find and understand the information. The resources will become more useful to the avocado industry by making the online resource interface more intuitive and by highlighting key points and materials.

Most of the modules require printed guides that contain all the necessary information from within the online resource. Most other fruit industries assessed in this review have presented their best-practice information in this form and it acts as a one-stop shop for best practice in each sector of the supply chain.

There is a lack of emphasis in the supply-chain education materials on management of temperature, fruit age, and fruit rots throughout the supply chain. This is reflected by unacceptable levels of fruit rots at retail. Therefore, a cool-chain management guide that emphasises the management of temperature and fruit age from harvest to retail is required. Emphasis on these issues will be a step towards improving the quality of avocados at retail.

Some differences exist between recommended best-practice in Australia and those recommended internationally or in the research. Differences are most prevalent in the harvesting and packhouse stages of the supply chain, and will need to be addressed in the coming phase of the project.

6. Appendices

Appendix 1. List of Australian avocado resources

Stage in supply chain	Title	Author	Date	Format	Information	Link
Pre harvest	*Grower self-assessment*	AAL		Form	Evaluation of best practices	Grower-self assessment form
	Canopy management guidelines for avocados in Australia	AAL	2009	Pamphlet	Guidelines for canopy management	
	The Avocado problem solver field guide	AAL and QDAF	2013	Handbook	Pest, disease and disorder identification and management	-
Harvest	*Avocado harvesting: growers and managers*	AAL	2011	Poster	Harvest guide for growers	Grower harvest guide
	Avocado harvesting: pickers	AAL	2011	Poster	Harvest guide for pickers	Harvest poster: pickers
	Avocado harvesting: pickers guide	AHR	2013	Video	Demonstration on good avocado harvesting	Harvesting video
	Maturity testing	AAL	2009	Factsheet	Dry matter testing information	Dry matter testing
Transport	*Avocado transport guide*	AAL	2011	Manual	Road and rail manual	Transport guide
	Avocado transport guide: quick reference	AAL	2011	Poster	Quick guide to manual	Transport guide poster
Pack house	*Bruising in avocados*	AHR	2012	Video	Bruising occurrence in avocados	Bruising in avocados
	Reject bin analysis	AHR	2013	Video	Determining fruit damage by RBA	Reject bin analysis
	Reject bin analysis form	AAL	2013	Form	Use to do RBA	RBA form
	Avocado grading poster	AAL	2011	Poster	Defects and grading scale	Grading poster
Wholesale	*Avocado handling: wholesale*	AAL	2011	Poster	Wholesale handling poster	Wholesale handling

Stage in supply chain	Title	Author	Date	Format	Information	Link
Ripening	*Avocado ripening manual*	AAL QDAF	2011	Manual	BPM ripening manual	Avocado ripening manual
	Ripeness poster	AAL	2011	Poster	Ripeness/colour chart	Ripeness chart
Retail	*Retailer training manual*	AAL	2015	Manual	Training manual for retailers	Retailer training manual
	Avocado handling: retail	AAL	2011	Poster	BMP for avocado handling in retail	Retail poster
	Woolworths back room ripeness guide 1	WoW		Poster	Ripeness guide for retail handlers	Poster 1
	Woolworths back room ripeness guide 2	WoW		Poster	Ripeness guide for retail handlers	Poster 2
Whole supply chain	*Little green book*	AAL	2011	Booklet	General information	Little green book
	Avocados QDAF	QDAF		Webpage	Avocado information kits	Avocado information website
	Talking avocados	AAL	Ongoing	Magazine	Industry information	Talking avocados
	Infocado	AAL	-2016	Report	Supply forecasts	Infocado

Appendix 2. List of international avocado resources

Stage in supply chain	Title	Author	Date	Format	Information	Link
Pre harvest	*Growing for quality*	California Avocado Commission (CAC)		Manual	GAP for avocados	GAP growing avocados
	Avocado management plan	SA Avo		Template	On-farm management plan	Farm management plan
	Good harvest manual	CAC		Manual	Check list for GHP	GHP checklist
	Controlling disease in South Africa	SA Avo	2009	Guide	BMP for disease control	SA disease management
	Good agricultural practice	CAC		Manual	Checklist for GAP	GAP checklist
Harvest	*Fruit moisture to determine quality*	SA Avo		Info sheet	Method	Moisture content for maturity
Transport	*Standard condition for transport*	SA Avo		Fact sheet	Refrigerated transport guide	SA transport
Ripening	*Ripening*	UC Davis	2015	Presentation	Ripening management	Ripening condition
	Ripening	UC Davis	2015	Presentation	Ripening management	Ripening condition
	Pre-condition and ripening	Calavo		Manual	GAP ripening manual	Ripening manual
	Ripening	UC Davis	2015	Presentation	Ripening management	Ripening condition
	Pre-condition and ripening	Calavo		Manual	GAP ripening manual	Ripening manual
	Ethylene ripening	NZ avo		Protocol	Ripening protocol	NZ ripening protocol
	Stages of ripeness	Calavo		Poster	Stages of ripe	Ripeness poster
Pack house	*Avo packing guide*	SA avo		Manual	BMP for packing/ picking avos	Avocado packing guide
Grading/ quality	*NZ grade standards*	NZ Avo	2008	Template	Grade standards and defects	Avocado symptoms manual
	NZ maturity testing	NZ avo		Guide	Domestic maturity testing	NZ maturity testing

Stage in supply chain	Title	Author	Date	Format	Information	Link
Whole supply chain	*FAO Post harvest operations*	FAO	2004	Compendium	Post harvest practices FAO	FAO post harvest
	FAO Post harvest operations	FAO	2004	Compendium	Postharvest practices FAO	FAO post harvest
	Avo symptoms manual	SA avo	2007	Manual	Avo symptoms manual	-
	FAO Post harvest operations	FAO	2004	Compendium	Post harvest practices FAO	FAO post harvest
	Avo symptoms manual	SA avo	2007	Manual	Avo symptoms manual	-
	Avocado source			Website	resource library	Avocado source website
	FAO Post harvest operations	FAO	2004	Compendium	Post harvest practices FAO	FAO post harvest
	Avo symptoms manual	SA avo	2007	Manual	Avo symptoms manual	-
	Seed to store	West Pak Avo		Poster	Supply chain summary poster	Seed to store
Retail	*Masters of merchandising*	Calavo		Information sheet	Information about Calavo brand	Calavo label
	Display and merchandising tips	CAC	2016	Poster	Handling at retail	Display and merchandising tips
	Avo handling video	NZ avo		Video	Handling at retail	Handling video
	NZ avo retail toolkit	NZ avo	2016	Toolkit	Summary of resources available	NZ retail toolkit
	NZ avo backroom ripeness guide	NZ avo	2016	Poster	Colour and temperature guide for retail	Backroom ripeness guide
	NZ stop immature avos	NZ avo	2016	Poster	Warning to stop immature fruit sales	Immature avo warning
	NZ Avo consumer ripeness guide	NZ avo	2016	Poster	Colour chart for choosing avos- don't squeeze	NZ consumer guide

Appendix 3. List of resources from other industries

Industry	Title	Author	Date	Format	Information	Link
Pear	*US pear handling guide*	USA pears		Manual	BMP for handling pairs through supply chain	US pear handling
Mango	*Mango post harvest best practice manual*	University of Florida	2014	Manual	Postharvest BMP for mangos	Mango best practice manual
	Mango ripening manual	QLD DEEDI	2010	Manual	BMP for ripening mangos	Mango ripening manual
Banana	*Banana Best Management Practices*	QDAF	2016	Manual	Environmental BMP for bananas	Banana BMP guide
Dried Grapes	*Dried Grape Best Practice Guide*	Dried Fruits Australia	2015	Manual	BMP for grape growing	Dried Grape Guide

Research Gaps

Research need

Research conducted in WA to 'ground truth' conclusions from Qld research. This could include examination of disease management (pre and postharvest), prevalence of different pathogens, the effect of high temperatures during harvest and optimising temperature management in domestic and export supply chains.

Justification

- Australian research has primarily focussed on fruit grown in SE Queensland. In Western Australia, limited trials have examined productivity of different rootstocks and the effect of temperature.
- However, approximately 40% of total National production is grown in WA, a region with very different soils and climate to growing areas in South East Queensland. A dry climate combined with high temperatures during harvest may reduce disease pressure, but increase other physiological disorders.
- For example, WA fruit may be optimally stored at either lower or higher temperatures than fruit grown in SE Queensland; Considine reported some preliminary data on the effects of growing temperature on quality of WA grown Hass in 2004, but this does not appear to have been followed up in detail.

Research need

Examine the effect on fruit quality and yield of different cooling strategies after harvest. This should include trials testing the effects of cooling delays between harvest and packing, comparison of room cooling with forced air and hydrocooling and cost–benefit analysis of different systems.

The project design should include examination of ripening uniformity (particularly for early and late season fruit) and logistical and quality issues associated with running cold fruit over a grading and packing line (eg sticker application to cold fruit, changed susceptibility to bruising).

Justification

- It is common practice for harvested avocados to be stored for a period before packing and cooling. Bins of fruit may be simply stacked inside cool-rooms, or even left under ambient conditions. While there is a stated objective to pick and pack within 24 hours, this is not possible at busy times of year or where orchards are remote from packhouses. Delays of several days are possible, during which time avocados may be only partially cooled.
- Delays in cooling to 5°C or lower can allow fruit to break through the inhibition period and start to ripen. This is most likely in late season fruit. Uneven or inadequate cooling

before and after packing also allows fruit to lose moisture, which can affect both yield and quality after ripening.

- The effect of cooling delays between harvest and packing has been studied in both South African and NZ grown fruit. These have shown that stem end rot and chilling susceptibility can increase significantly with cooling delays of more than 24 hours. While disease may be less of an issue in Australia than in NZ, harvest temperatures are often higher and humidity may be lower, increasing moisture loss. This very likely contributes significantly to uneven ripening after storage.
- In California avocados are hydrocooled. During hydrocooling, products are likely to gain moisture; uptakes of 2–5% are common for other products. In avocados, water uptake has been demonstrated to result in more homogenous ripening, suggesting there could be additional benefits from this cooling method.

Research need

Develop targeted disease approaches based on regional and climatic variables. This could include examination of when increased disease prevalence means fruit should be clipped, rather than snapped, at harvest; the effectiveness of fungicide applications during flowering; the effect of delays in fungicide application after harvest.

Justification

- Fungicides are commonly applied to Australian avocados to control stem end rot and anthracnose.
- The pathogens that infect avocados are often latent diseases that do not develop until fruit starts to soften. Infection may have occurred during flowering, or early in fruit development. Non-systemic fungicides have limited effectiveness against diseases already established inside fruit.
- The effectiveness of postharvest fungicides has been reported as around 50% or less. These studies often applied fungicide immediately after harvest; in reality, fungicides may be applied several days later. In other crops, fungicide applications more than 24 hours after harvest have been shown to have little effect.
- Application of fungicides during flowering may therefore be a better way to control postharvest diseases than postharvest applications. In addition, pathogen load is likely to vary with environmental conditions, with dry areas having lower pathogen loads in general.
- Late applications of fungicides may therefore be ineffective, incur significant expense to the grower, and risk breaching increasingly stringent MRLs in domestic and overseas markets.

Research need

Examine the effectiveness of surface coatings and waxes at retaining postharvest quality, reducing chilling sensitivity and improving customer satisfaction with avocados from different regions of Australia.

Justification

- Recent work overseas has reported excellent results with surface coatings and waxes. Waxes modify the atmosphere inside fruit, increasing CO_2 and reducing moisture loss. Waxes may have anti-fungal GRAS agents added; thyme oil has been proposed as one such product. Waxes have been reported to enhance resistance to chilling, reduce disease, limit weight loss and result in more even ripening.
- Coatings need to be formulated to suit the respiration of the product; too thick a coating can limit gas exchange and result in off flavours, while too thin a coating may have no effect. Models of this have been developed for NZ fruit. Skin properties are likely to vary by cultivar, region and maturity.

NSW GOVERNMENT | Department of Primary Industries

AV15010

Avocado Cool Chain Best Practice

November 2016

Introduction

Disease management in any commercial orchard situation is critical for the success of horticultural ventures. The delicate fruit of avocado is highly susceptible to body rots and stem end rots which poses a complex management issue for producers and can cause significant post-harvest losses. Maintaining fruit quality throughout the supply chain relies on effective disease management within the orchard, during harvest and during post-harvest storage and handling. This review examines current knowledge of disease management issues and control measures in the avocado industry, as part of a larger review examining best practice for avocado production:

- **AV15010 Task 5**: Review current and potential developments in chemistry and practices for managing avocado post-harvest disease.

There are three commonly used races of rootstock for avocado production: West Indian Race (*Persea americana var. americana),* Guatemalan Race *(P. americana var. guatemalensis)* and Mexican Race (*P. americana var. drymifolia).* The West Indian race is native to the lowlands of Central America, the Guatemalan race is native to the highlands of Guatemala and the Mexican race is native to the subtropical area around Mexico. Of these three races a myriad of cultivars are produced (Bill et al, 2014):

- ‘Hass’ a common Australian cultivar is a Guatemalan x Mexican hybrid;
- ‘Fuerte’ is a Mexican x Guatemalan hybrid;
- ‘Pinkerton’ is a Guatemalan hybrid;
- ‘Fuchs’ is a West Indian cultivar;
- ‘Bacon’ is a Mexican x Guatemalan hybrid;
- ‘Edranol’ is a Guatemalan hybrid;
- ‘Ryan’ is a Mexican x Guatemalan hybrid; and
- ‘Ettinger’ is a Mexican cultivar.

Avocado pathogens associated with post-harvest rots

There are a number of key pathogens affecting the avocado industry in Australia. Pathogens are typically classified as either body rots or stem-end rots and include the following:

- Anthracnose is one of the leading causes of body rots in post-harvest fruit. It is caused by the fungi *Colletotrichum gloeosporioides* (= Glomerella cingulate) and/or *C. acutatum*, and remains as a latent infection whilst fruit it still on the tree;
- Stem-end rots are caused by a variety of fungal pathogens including *Fusicoccum aesculi* (formally *Dothiorella aromatic*)*, Lasiodiplodia theobromae, Phomopsis perseae, C. gloeosporioides;*
- Pepper spot is also caused by *C. gloeosporioides* and is more prevalent on trees affected by *Phytophthora cinnamomi;*
- Sooty blotch is caused by *Stomiopeltis spp.;*
- Cercospora spot caused by the fungal pathogen *Pseudocercospora purpurea.*

Contributing factors for Pre-harvest infection

Many of the fungal pathogens outlined above occur naturally on the avocado trees as part of the natural microflora. They are typically found on dead leaves and twigs both on the tree and those that have already fallen on the ground. Pathogens have also been identified on mummified fruits, dead fruit in the canopy and tree skirting. Most rots do not express symptoms until after the fruit has been harvested. Much of the conventional orchard treatment for disease control is focused on the fruit as it develops on the tree and then post-harvest during packing.

There is now a mounting body of evidence to suggest that latent infections actually commence during **flowering**. The fungal spores land on the inflorescence then remain dormant until post-harvest (Demoz & Korsten, 2005). The dormancy is believed to be maintained by anti-fungal dienes present within the fruit during its growth. After the fruit is harvested the level of these dienes declines allowing the growth of fungal hyphae leading to rot within the harvested fruit. Temperature also influences when spores are likely to germinate. Spore germination and appressorial development by *C. gloeosporioides* was inhibited by temperatures below 14°C for at least 24 hours. This species required temperatures above 16°C for longer than 48 hours to initiate appressorial formation, with 22-23°C was the preferred temperature range (Everett & Pak, 2002).

Environmental conditions during the growing season are a contributing factor to disease development. Fungal pathogens prefer warm moist conditions with high humidity. Densely vegetated tree canopies provide ideal conditions for fungal spore production and germination. Prolonged wet weather is also an issue as the adhesion of protectant fungicides is reduced and higher moisture levels (and humidity) encourage fungal growth (Coates et al, 2001; Everett, 2002).

There may be a correlation between **tree vigour** and disease incidence as observed by Willingham et al. (2004). Non-vigorous trees were observed to have lower levels of anthracnose infection and in some cases also lower levels of pepper spot. This is thought to be a function of higher levels of calcium (up to 40%) detected within the fruit. The fruit from non-vigorous trees was however noted to have a higher incidence of *F. aesculi* infection and the fruit were smaller and took longer to ripen which may impact on its overall marketability. The correlation between lower calcium and vigorous shoot growth (resulting in lower calcium levels within the fruit, hence higher disease incidence) may have implications for ongoing management programs. The overall health of the trees needs to be considered. Trees that are stressed by drought, salinity, nutrient deficiency and other pathogens (such as the root attacking pathogen *Phytophthora cinnamoni*) leaves them more vulnerable to disease (Willingham et al, 2004).

The **genetic progeny** of the trees can have a significant impact on the level of post-harvest rots. Willingham et al. (2006) observed significant reductions (up to 87%) in the incidence and severity of stem end rot in trees that had been grafted onto the Guatemalan race rootstock ‘Velvick’. Trees that had been grafted onto Mexican race rootstock ‘Duke 6’ consistently exhibited high levels of disease incidence in post-harvest fruit. Fruit from ‘Velvick’ rootstock took longer to ripen and showed both a reduction in the incidence (29%) and severity (49%) of anthracnose infection. Stem-end rots were also significantly (85%) less when grafted to ‘Velvick’ compared with ‘Duke 6’ rootstock.

This variability between **rootstock races** may be attributable to differing levels of minerals in the fruit. Leaves sampled from ‘Duke 6’ trees had significantly higher concentrations of potassium and nitrogen and significantly lower concentrations of magnesium and calcium when compared with the ‘Velvick’ rootstock. This resulted in lower ratios of Ca+Mg: K. Hofman et al. (2002) also found that a correlation between calcium and magnesium concentrations and the ratio of these minerals to potassium resulted in reduced disease incidence. It is believed that calcium inhibits the breakdown of cell walls. The uptake of calcium involves the transpiration stream therefore may be affected by environmental factors such as temperature and rainfall (or irrigation) (Everett et al, 2007).

Individual **differences between fruit** on the same tree may also be a contributing factor for disease occurrence. Pak et al. (2001) noted that fruit with significant ridging and/or protuberances on the skin surface may be exposed to a higher risk of damage via bruising or abrasion during harvest. A correlation between the height of surface ridging and increased disease incidence was observed. This aspect may require further investigation to provide direction for future breeding programs.

The **position of the fruit** on the tree may also be a contributing factor to post-harvest rot incidence. Everett & Pak (2001) observed a higher incidence of rots in fruit grown on the lower half of the tree. Fungi that cause rots in avocado are primarily water dispersed. Fruit on the lower half of the tree may have a higher risk of fungal exposure as water drips down through the canopy over the contaminated twigs and leaves or splashes up from contaminated mulch at the base of the tree. Even the position of fruit in relation to the sun may impact disease occurrence. Fruit growing on the sunny exposed sides of trees were noted to have a higher incidence of pepper spot, likely as a result of stress imposed by sun damage (Willingham et al, 2004).

Everett (2002) detected several fungal pathogens within **orchard shelter belts** raising the prospect that windbreaks may provide a potential inoculum source, dependent on the species present. Pathogens were isolated from *Cryptomeria japonica* (Japanese cedar), *Casuarina cunninghamiana* (She-oak) and poplar, all popular shelter belt choices. Eucalypt species and bamboo were noted to not support fungal colonies that pose a threat to avocados.

Contributing factors for Post-harvest infection

Harvesting hygiene and technique both play a significant role in potential pathogen inoculation pathways. Plucking versus clipping the fruit during harvest can impact on disease levels. Plucking creates a large jagged wound at the base of the fruit increasing the surface area available for pathogen entry. Plucking fruit may also release more spores from the tree which then readily infect the wound site (Everett, 2002). Clipping reduces this surface area however the length of the pedicel can impact rot entry. Clipping fruit with unsterilized secateurs may however pose a risk as the secateurs can also effectively inoculate the fruit during harvest via contamination with infected xylem material (Hartill & Everett, 2002).

Fruit are commonly dipped in a post-harvest fungicide and/or insecticide prior to packing and transport. The solution in which the fruit is dipped requires careful selection as dips do not provide consistent control for all pathogens. For instance, **fungicide dips** often provide effective control for anthracnose however don't necessarily confer protection against stem-end rots. Fruit dipped in insecticide alone without the addition of a fungicide basically inoculate the fruit in a "spore bath" infecting the fruit with fungal pathogens in the process (Everett, 2002). The timing of the dip application also plays a role with the sooner the fungicide is applied post-harvest the greater the control over fungal pathogens.

The **temperature** fruit are stored and ripened at can have a drastic impact on the incidence of post-harvest rot. Everett (1998) observed that appressoria of *Colletotrichum gloeosporioides* do not form below 12°C and that storage at 5°C can kill up to 50% of the spores after 14 days. However, *C. acutatum* was insensitive to low temperatures and infections by this fungus were not reduced by storage at 5.5°C before ripening. Hopkirk et al. (1994) demonstrated that fruit ripened at 20°C (that had been previously cool stored) had fewer post-harvest rots. Fruit ripened at 25°C tended to have a higher disease incidence and at 30°C fruit failed to ripen properly. The best result (in terms of disease management) was achieved by storing fruit at around 6°C before ripening at 15°C. The time when fruit are first placed in cool store may also be a contributing factor. Fruit placed in cool store around 12 hours post-harvest had a reduced disease incidence compared with fruit placed in cool store at only 6 hours or 24 hours post-harvest (Everett, 2002). The length of time fruit is held post-harvest prior to selling is the final link in the production chain. Fruit held for more than 30 days in storage prior to selling exhibited a marked increase in the incidence of post-harvest disease and disorders (Everett, 2002).

Disease Management Options

Disease management within an orchard must address a range of infection pathways and inoculum sources to provide adequate disease suppression. Maintaining low levels of disease presence will greatly assist future production seasons as well as reduce the labour and cost involved in disease management. Given the variety of possible infection pathways a range of options needs to be considered including both pre-harvest and post-harvest situations. Currently there are a variety of control options addressing both cultural and chemical control options.

Pre-harvest control

Given the likely infection pathway of many body and stem-end rots occurs during flowering, pre-harvest disease management strategies are critically important for managing disease incidence. Orchard management options include:

- Fungicidal options;
- Tree management;
- Irrigation and fertilisation regimes;
- Use of biocontrol options.

There are currently 170 registered fungicide products for use on avocados within Australia (Australian Pesticides and Veterinary Medicines Authority, accessed 21st October 2016). These products include both pre- and post-harvest chemicals and include a range of active ingredients that may control fruit rots including:

- Azoxystrobin
- Phosphorous (phosphonic acid) acid present as mono-di potassium phosphonate
- Foestyl-aluminium
- Propiconazole
- Copper present as cupric hydroxide, copper oxychloride, tribasic copper sulphate, and ammonium acetate
- Difenoconazole
- Prochloraz
- Thiram

Pre-harvest fungicides are typically applied as a foliar spray on a 28-day spray schedule. Fungicides are protectant in nature hence must be applied frequently throughout the growing season. This cycle may be further condensed in the event of wet weather where spraying may be required every 14 days or so as most fungicides are not rain fast. Traditionally fungicides were applied to the fruit during the growing season to offer pathogen protection during fruit development however there is now evidence that fungal infection may occur as early as flowering. Application of suitable fungicides during flowering may help to suppress spore germination and hyphae development in the flowers, prior to the fruit becoming infected. Spraying can then be maintained during the growing season until harvest (Coates et al, 2001). The frequency of spray application has also been considered by Everett & Pak (2001) who observed that at least 5 applications of fungicide throughout the growing season offered reasonably good disease control. Orchards with less than 5 fungicidal applications throughout the growing season did not achieve adequate disease control. The industry recommendation is for 8 spray applications per season. A further study by Everett et al. (2007) indicated that fruit sprayed less than 8 times during the season actually exhibited greater levels of body rots when compared with non-treated fruit. This indicates that the level of treatment was enough to potentially reduce the levels of beneficial microorganisms within the orchard yet not enough to provide adequate disease control.

Copper fungicides offer reliable disease control however being heavy metal based there are concerns regarding copper residues accumulating in the soil with repeated use over time. There is now evidence that copper residue in soils is having a negative impact on soil microbes, earthworms and beneficial mycorrhizal relationships (Everett et al, 2008). Copper based products can also leave a residue on the skin of the fruit which must be manually removed (if possible) during the packing process. Ineffective removal of the residue can even lead to market rejection (Korsten et al. 1993). This residue is a particular issue in rough skinned cultivars which may both accumulate more residue and be harder to clean (Coates et al, 2001).

The type of fungicide used needs to be carefully considered with a view to preventing or reducing the risk of resistance build-up within the fungal pathogen group. Alternating between different chemical groups can assist with this. Fungicide selection must also give consideration to the type of pathogen being targeted as not all fungicides offer control for all organisms. Spray regimes should be individually developed for each crop based on problem pathogens specific to that property. A great deal of research has been undertaken on the use of specific fungicides/combinations for disease management of avocados, a selection of which can be found in **Appendix 1.** A summary of a 2014 strategic agrichemical review process on avocados is also detailed in **Appendix 2.** It is important to note however that registrations for all chemical use in Australia should be checked prior to use.

As discussed earlier consideration should be given to the **rootstock** trees are grafted onto. There were demonstrated reductions (up to 85%) in disease incidence by grafting onto West Indian races as opposed to Mexican races of rootstock (Willingham et al, 2006; Dann et al, 2016).

Nutrient accumulation in fruit may be able to be manipulated via the **fertiliser regime** for the crop. Willingham et al. (2006) trialled reducing nitrogen based fertiliser to nil which subsequently reduced nitrogen concentrations and ratios of N: Ca in the fruit peel which correlated to a reduced incidence and severity of anthracnose infection, regardless of the rootstock. This effect may be reliant on the age of the rootstock also, as the disease suppression was observed to decline over time as the trees aged associated with a declining level of anti-fungal diene. According to Everett & Pak (2001) orchardists should aim to achieve a Ca+Mg: K ratio of at least 0.07 for the purposes of disease protection.

Pruning trees is a simple strategy for orchard managers to reduce disease incidence. Improving aeration within the canopy reduces the suitable microclimate for fungal pathogens. Reducing canopy density in this way may also direct more mineral to the fruit accounting for the higher levels of calcium which contributes reduced disease incidence (Hofman et al. 2002).

Ensuring that trees' environmental needs are met, by way of maintaining **soil moisture levels** or reducing exposure to saline conditions, reduces the stresses placed on the plant. Plants under stress exhibit reduced immune responses rendering them more susceptible to infection. By maintaining healthy plants this not only ensures plants are producing fruit at capacity but are also less vulnerable to pathogen attack (Perez-Jimenez, 2008).

Controlling other pests and pathogens within the orchard can also reduce the risk of infection by fungal pathogens. Insects (both chewing and sap sucking) that wound the skin of the fruit provide entry opportunities for fungal pathogens. The insects themselves may even act as transmission pathways by inoculating fruit during the feeding process. There are a range of registered insecticides in Australia available as part of a standard orchard management program. Controlling other pathogens such as root rot (e.g. *Phytophthora spp.*) maintains healthy vigorous plants that produce better quality fruit and are more resistant to pathogen attack.

There is growing awareness around the use of agri-chemicals and a desire within the industry and community to seek alternative disease control options to reduce chemical usage in the environment as well as offer safer options for growers concerned about the health implications of repeated chemical exposure. It is for this reason that **biocontrol applications** are growing in popularity. Suitable biocontrol agents must be able to combat a variety of environmental extremes and be able to withstand exposure to UV radiation, dry conditions, high temperatures and low nutrient environments (Ippolito & Nigro, 2000).

A number of naturally occurring antagonists have been identified in the field and are being developed into commercially available products. The bacterium *Bacillus subtilis* in particular has proven to be a highly effective disease suppression agent. Given that fungal infection can occur through the inflorescences inoculating flowers with biocontrol agents such as *B. subtilis* can prevent spore germination and hyphae development prior to the fruit being infected. Avogreen™ is a commercially registered product containing *B. subtilis* and has achieved good control of fungal infection when applied both before and after the arrival of the pathogen by either suppressing spore germination or supressing hyphae development (Demoz & Korsten, 2005; Korsten et al, 1995). The mode of action for this antagonist is likely a combination of the production of inhibitory substances by the bacterium as well as competition for nutrients. Pre-emptive colonisation may also contribute to fungal decline (Korsten & De Jager, 1995). As some infection may occur during harvest (where harvest-induced wounds are colonised by fungi) it may also be appropriate to inoculate fruit with biocontrol agents just prior to or just after harvest (Ippolito & Nigro, 2000). Incorporating *B. subtilis* into commercial wax preparations may also be an option (wax is often applied post-harvest to slow ripening). Using a combination of biocontrol and a commercial fungicide may also provide effective disease control (Janisiewicz & Cornway, 2010).

Post-harvest control

Post-harvest disease management strategies focus on the storage of fruit. Storage conditions are designed to maximise the shelf life of the fruit whilst maintaining the necessary quality required at the retail end of the supply chain. From the packing shed to the market shelf there are a range of control options that could be incorporated to minimise fruit losses associated with post-harvest rots.

A consistent recommendation is to **not harvest fruit in wet conditions** (rain or dew). A high incidence of lenticel damage has been observed in fruit picked in wet conditions along with a variety of other physical disorders such as vascular browning (Duvenhage, 1993; Köhne & Kremer- Köhne, 1995). Fungal spores can also be released in wind and rain and handling fruit in these conditions could contribute to infection of the fruit, particularly for stem-end rots (Bill et al, 2014; Duvenhage, 1993).

Modifying **harvesting technique** may help to reduce rots. Clipping the fruit instead of plucking it from the tree provides a smaller wound site on the fruit reducing the surface area that can be infected by pathogens. When using secateurs to carry out the clipping ensure that a short length of the pedicel is retained on the base of the fruit and secateurs should be sterilised in between fruit (e.g. dipping in an ethanol solution) to prevent inoculation of fruit with contaminated xylem element material (Hartill & Everett, 2002). Harvested fruit should **not be placed on the ground** so as to minimise contamination by other pathogens such as *Listeria spp.* that may be present on the soil surface (Ultee et al, 1999).

Fruit is **sprayed or dipped** with fungicide such as prochloraz after picking and prior to packing. Application within 2 hours of picking offers the best protection however there is still significant benefit conferred if applied within 24 hours of picking (Everett, 2002). Combining application of commercial fungicide (such as prochloraz) and biocontrol agents may also prove beneficial (Janisiewicz & Cornway, 2010).

Temperature recommendations for **cool chain storage** vary according to the age of the fruit, cultivar and harvest season but there is a general consensus among the available literature of between 4-8°C (Hopkirk et al, 1994; Everett, 2002) and fruit should be placed within cool store around 12 hours post-harvest (Everett, 2002). Higher temperatures can contribute to other physiological disorders such as vascular browning and softening (Bill et al, 2014). Fruit should not be stored at too low a temperature so to avoid chilling injury. Further work on this area may help to identify a standardised cool chain procedure and ideal temperature regime. The ideal temperature fruit should be ripened at is around 15°C, especially if fruit had been stored at around 4-8°C prior to ripening (Hopkirk et al, 1994). Higher temperatures saw a correlated increase in disease. Exposure to a controlled atmosphere (e.g. ethylene) during ripening may also infer a disease reduction benefit.

Retailers should ensure fruit is **not held too long** in storage prior to sale (i.e. less than 30 days) as the longer it is stored the higher the incidence of disease (Everett, 2002). If fruit cannot be moved on quickly it needs to be held in cool store at around 4°C once the fruit nears optimum ripeness.

Post-harvest **heat treatments** offer a chemical-free option for managing disease during post-harvest storage. There is no residue left on the fruit surface however the treatment must be applied soon after harvest. Heat treatments can inhibit spore germination and mycelial growth with the added benefit of inducing defensive responses in the fruit such as activating phenylalanine ammonia lyase and increasing biosynthesis. Heat treatment may also help to physically obstruct pathogen entry by inducing greater lignification around wound sites. (Kim et al, 1991; Rodov et al, 1996). The duration of heat application and temperature may vary between cultivars and correct application is essential to ensure fruit is not damaged. Karunaratne & Adikaram (1998) observed a significant reduction in anthracnose incidence by applying a hot water treatment to avocados at 45°C for 15 minutes at harvest.

Controlled atmosphere storage involves manipulating certain atmospheric gases to a preferred level during storage and transport. Typically O_2 levels are reduced and CO_2 levels are increased in order to reduce respiration and ethylene production, and hence delay the ripening process (Spalding & Reeder, 1975). The level of atmospheric gases varies with cultivar but typically relies on a 1-2% O_2 and 10% CO_2 atmosphere to reduce the incidence of anthracnose. The level of O_2 must be considered however as too low a level may incite O_2 shock resulting in cell damage and a higher risk of anthracnose (Bangerth, 1979; Eksteen & Truter, 1985).

Modified atmosphere packaging (MAP) involves altering the atmospheric composition of CO_2 and O_2 prior to the fruit being stored within a plastic film. Different atmospheres are produced by flushing with a predetermined gas concentration prior to packing and cannot be controlled once fruit has been packed. There are some instances where additional components are added prior to the bags being sealed to control CO_2, water vapour, ethylene and essential oils. MAP with an ethylene component has been shown to reduce the incidence of anthracnose (Pesis et al, 2002) however other studies have found that whilst storage life was prolonged the incidence of anthracnose was not reduced, likely as a function of the high humidity within the bags (Eksteen & Truter, 1985).

The use of **natural oils** is being investigated for the potential of providing disease control. Essential oils are attractive due to their biodegradable nature, low risk of resistance, their volatility and are generally regarded as safe. Sellamuthu et al. (2013) investigated the use of thyme oil for controlling disease post-harvest. A Whatmar filter impregnated with thyme oil was placed amongst the fruit whilst in MAP. Fruit was then stored for 18 days at around 10°C. In this particular study the incidence of anthracnose was reduced to a similar level of conventional treatments (e.g. fungicide application). The required texture and flavour of the fruit was maintained and the mode of action is believed to involve the promotion of higher phenylalanine ammonia-lyase activity level due to the synthesis of phenolic compounds.

Lippia scaberrima and spearmint oil was also investigated for their anti-fungal properties (Regnier et al. 2010). This study found the oil and the terpenoids tested significantly inhibited fungal growth of *C. gloeosporioides, L. theobromae* and *Alternaria* spp. The oils were sprayed onto the fruit whilst on the packing line and the fruit were then placed in cool store at 10°C for around four weeks before being ripened at 22°C. Despite the initially positive results the *Lippia* oil did reduce in efficacy over time indicating potential limitation for use as a fumigant. One of the primary components of the oil, limonene, was also shown to induce fungal growth when applied as a vapour indicating that limonene-rich oils are unlikely to be suitable disease control agents.

The use of lemongrass oil in combination with MAP has also been assessed (Mpho et al, 2013). Results suggest that the combination of MAP and lemongrass oil significantly reduce the incidence of anthracnose as well as a number of other physiological disorders. Studies assessing just MAP alone found that whilst it provides useful benefits for minimising physiological disorders such as vascular browning there were issues with postharvest disease possibly as a function of the high humidity environment. By adding an essential oil with known antimicrobial properties a reduction in disease incidence was achieved, similar to that of commercial fungicidal treatments. Other essential oils were assessed in this particular study including: basil oil, ,citronella, peppermint oil, eucalyptus oil, tea tree oil, lemon oil and cinnamon oil, grape oil however lemongrass oil provided the most effective suppression of anthracnose. This treatment combination also delayed ripening from 5 days (with the commercial fungicide treatment) to ten days, effectively increasing the shelf life of the fruit. With further market development these treatment options may prove viable for small packing operations, organic growers and for growers wishing to reduce their reliance on commercial fungicides.

A review of industry funded research into avocado fruit rots by Everett (2002) identified several novel treatment options that may offer viable disease control including the application of acidified permanganate and the use of Janola. This review also identified a number of novel treatment options that did not offer acceptable disease control:

- Application of Biocoat™ (a mixture of beeswax and olive oil);
- Elicitors such as methyl jasmonate;
- Some biocontrol agents such as Serenade™;
- Application of a 76% ethanol solution during packing;
- Application of neem oil;
- Application of food grade antioxidants;
- Use of CO_2 shock treatment;
- Commercial products such as Avosan™ and Sporekill™

Future Direction

There are a number of novel disease management options that may rate further investigation for their potential application in the avocado industry:

- New biocontrol agents or application options;
- Further investigation into the cool store process to develop an industry standard or guideline for growers;
- Closer examination of essential oils such as thyme oil and lemongrass oil;
- Determination of the fungicide resistance status in pathogens causing fruit rot diseases in Australia.
- New fungicide options or a combination of conventional fungicides with biocontrols;
- Investigation of the fungal pathogen genome to identify targeted solutions to disease control (Beever et al, 2005);
- Investigation of the avocado genome to identify areas to be targeted for resistance breeding;
- Further investigation into the genetic provenance of the rootstock;
- Developing a predictive model of disease potential. Given the importance of nutrient interactions in reducing disease incidence Dann et al. (2016) believes there may be a potential to measure the ratio of nitrogen: calcium in the skin of unripe avocado to provide an indicator of potential disease occurrence in fruit after harvest. Everett et al. (2003) has suggested that measuring the levels of fungal pathogens present on the leaves during the production season may provide a potential indicator of post-harvest rots. There was some variation in the level of inoculum depending on where the sample came from (e.g. near or far from the ground, position within the canopy) even what part of the leaf was sampled. Whilst a correlation was found between the levels of anthracnose and *Botryosphaeria spp.* found, and the level of post-harvest rot detected, this area requires more refinement before it can be used as a practical predictive tool.

Research in other fruit growing crops may have potential for application within the avocado industry. Some novel approaches for disease management that could be further investigated for the application to the avocado industry may include:

- Application of bicarbonate solutions (including ammonium-, potassium- and sodium-bicarbonates) has been shown to control fungal diseases on grapes, cucurbits, citrus, strawberries and peppers. The mode of action of these solutions involves moderating the pH on the leaf/fruit surface, inhibiting fungal growth;
- Application of clay-based products has provided effective fungal control on apples and grapes. The mode of action for these preparations involves increasing the concentration of aluminium on the plant surface (resulting in increased uptake of aluminium) and acidifying the pH on the plant surface, inhibiting fungal growth. Commercial brands such as Ulmasud® and Myco-Sin® were tested (Schmitt et al. 2002, Hofmann, 1996);
- In apples a yeast pheromone and a peptide molecule similar to that found in *C. gloeosporioides* can inhibit the development of appressoria, providing a new direction for biological control research (Al-Samarrai et al, 2002).

All new techniques and disease management options must be thoroughly evaluated on the different commercial varieties grown in Australia. Aspects such as growing conditions, cultivar, maturity and pre-harvest management may all impact on the success of new disease control strategies. Further evaluation may be required on a combination of the pre- and post-harvest disease control strategies as there may be cumulative effects or interactions when multiple strategies are employed at once. Assessing these options in isolation and in combination will ideally lead to the production of industry standards against which growers may incorporate these techniques into their current orchard management scheme with confidence.

Appendix 1: Commercial Fungicide Trial Review

Reference	Findings
Coates et al, 2001	• Azoxystrobin formulation Amistar™ and trifloxystrobin formulation Flint™ * significantly reduced anthracnose incidence when compared with the control • Kocide™ (copper hydroxide) did not significantly reduce anthracnose in this trial but Kocide™ + Amistar™ was effective • Kresoxy-methyl formulation Stroby™* was ineffective for anthracnose • It's not feasible to apply strobilurin fungicides on a 28-day spray schedule due to the high risk of developing resistance • This trial looked at applying Amistar™ or Flint™ twice during flowering and twice just before harvest, with Kocide™ used for the remainder of the growing season, and saw a significant reduction in anthracnose, stem-end rot and sooty blotch • Amistar™ is an effective postharvest dip for the control of anthracnose • Postharvest application of prochloraz is not effective against stem-end rot pathogens *Dothrioella spp.* and *L. theobromae*
Demoz & Korsten, 2005	• Postharvest fungicide applications to treat latent infections cannot ensure complete protection unless the fungicide can penetrate through the fruit cuticle and reach the site of the infection
Everett, 2002	• Copper based fungicides have consistently performed the best of those tested and in combination with Benlate™* during flowering and early fruit set, followed by post-harvest fungicide dipping in prochloraz provides effective disease control • Prochloraz application within 24 hours provides acceptable disease control however within 2 hours provides the best control • Bensimidazole group fungicides were tested in lieu of prochloraz. Benlate™ was found to perform well however is no longer commercially available. Fungaflor™* was not effective • Trizol fungicide Nustar™* worked as well as prochloraz • Rappor Plus™* and Panoctine Super™* were ineffective for disease control • Foli-R-Fos™ was not effective as a dip but when applied in the orchard or imbibed intro the fruit there was effective disease control • Applying fungicide to the picking wound immediately after harvest, in the orchard, provided good control of stem-end rots
Everett, Owen, Cutting, 2005	• Copper hydroxide have the best rot control followed by azoxystrobin and carbendazim • Copper fungicides are a heavy metal and can accumulate in the soil to undesirably high levels, so their use is not necessarily sustainable • Fluazinam consistently and effectively inhibited spore germination • Strobilurins were the next most effective with kresoxim-methyl the lead performer • Copper hydroxide inhibited spore germination but only at high concentrations • Benomyl did not inhibit spore germination of *Botryosphaeria spp.* • Prochloraz and pyrimethanil were only effective against *Botryosphaeria spp* • Strobilurin group only effective against mycelial growth of *C. acutatum* • Prochloraz was the most effective inhibitor of mycelial growth of 4/5 fungi tested • In the field copper hydroxide was the most effective followed by azoxystrobin, however the best control was achieved by a combination of the two • It seems that the mechanism of inhibiting infection is not important, either inhibiting spore germination or mycelial growth will provide protection
Everett, Stevens, Cutting, 1999	• Trees received either two applications of benomyl* during flowering or were left unsprayed. Stem-end rot was reduced in fruit from trees which had been sprayed however there was no significant reduction in body rot

Everett et al, 2008	• Field testing of boscalid/pyraclostrobin, copper hydroxide (Kocide Opti™* and Champ DP™), dithianon, fluazinam and biological Biostart Target™ were applied as sprays • Fluazinam, boscalid/pyraclostrobin, Kocide Opti™ and Champ DP™ significantly reduced numbers of body rots compared with the control • Products were applied from February-October by a pressurised handgun using approximately 8L/tree • Copper is of concern due to its detrimental effects on earthworms and microbial activity in the soil
Perez-Jimenez, 2008	• Preharvest chemical treatments with copper fungicides, alone or in combination with other fungicides, are effective when floral buds begin to swell and throughout fruit development • Postharvest treatments with prochloraz were effective against *Colletotrichum spp.* • Antagonistic water dip treatments (i.e. using suspensions of *B. subtilis*) was at least as effective as prochloraz in controlling disease
Smith et al, 2011	• The standard practice in Australia is to dip fruit in prochloraz after harvest • Testing with fludioxinil, NaturalGreen™ or EcoCarb™ resulted in significantly less anthracnose developing in fruit than in water-dipped controls however only the fungicide treatments resulted in significantly less stem-end rot • The most marketable fruit were from the fungicide and EcoCarb™ treatments • Field trials showed that spray applications of mancozeb fungicide, copper + azoxystrobin or "Product A" significantly reduced anthracnose • Stem-end rot was least severe in fruit treated with "Product A" • EcoCarb™, Aminogro™ and Bion™ field sprays were not effective • NaturalGreen™ had effects on skin N, Ca, K and Mg • NaturalGreen™ is composed primarily of $CaCO_3$ and $MgCO_3$ and is high in silicon and trace elements such as Fe, Cu, Mn, Se and Zi and aids in cellular stability and ionic exchange to improve natural resistance against disease. It had appositive effect on disease reduction during this trial • EcoCarb™ (Organic Crop Protectants) is registered as an organic fungicide in Australia and is based on activated potassium bicarbonate. It changes the pH level on the leaf surface disrupting fungal and cell walls • Aminogro™ (Organic Crop Protectants) is marketed as a "plant crop bio stimulant" and is based on chitosan derived from prawn shells, converted to amino acids, polypeptides, proteins and fortified with trace elements. It purportedly helps stimulate the plants' immune system to minimise fungal damage • Bion™ (Syngenta) contains the active compound acibenzolar-S-methyl, a known plant defence activator • Scholar™ (Syngenta) is a fungicide containing the active ingredient fludioxinil. It showed good potential as a postharvest dip to reduce the severity of anthracnose and stem-end rot. It is a Group 12 fungicide unrelated to any others currently used in avocado production and hence may have value being incorporated into anti-resistance strategies • Serenade MAX™ is a biocontrol agent based on a strain of *Bacillus subtilis* • Kasil 2040™ is a silicon based product however produced inconsistent results • Dithane™ Rainshield™ is a formulation of the protectant fungicide mancozeb with claimed improved rain fastness, and consistently performed well during this trial • Product A was shown to have a positive effect on disease reduction during this trial however there is no detail in this paper as to the identity of Product A

*need to check registration in Australia, may not be able to be used on Avocados

Appendix 2: Current and potential fungicides for disease control in avocados (Davis, 2014).

Active ingredient	Name	Availability	IPM rating	WHP, days	Chemcal group	Activity
azoxystrobin	Anthracnose, stem end rot	A	✓✓✓	7	11	Systemic
bromochloro dimethylhydantoin	Bacteria, Fungi & Hygiene - Post-harvest	A		NR		
chlorine as Ca hypochlorite	Bacteria, Fungi & Hygiene - Post-harvest	A	x	NR		
copper	Anthracnose	A	✓	1	M1	Contact, protectant
	Cercospora spot	P				
	Sooty blotch	P				
	Trunk and stem canker	P				
difenconazole	Cercospora spot	P	✓✓✓		3	Protectant, curative
fludioxonil	Anthracnose, stem end rot	P	✓✓		12	Systemic
fosetyl as Al salt		A	✓✓	1	33	Systemic, protectant, curative
iodine	Bacteria, Fungi & Hygiene - Post-harvest	A	x	NA	M	Contact
mandipropamid (REVUS^)	Phytophthora root rot	P	✓✓✓		40	
metalaxyl-M	Phytophthora root rot	A		7	4	Systemic, Protective, Curative
phosphorous acid (including PER13624 expires Aug 2014). Addition to label in progress.	Phytophthora root rot	A		NA	33	Contact
phosphorous acid	Trunk and stem canker	P				
prochloraz	Anthracnose, stem end rot	A		NA	3	
pyraclostrobin + metiram (AERO^)	Anthracnose, stem end rot	P	✓✓		11+M2	Protectant, curative
thiram (BARMAC THIRAM)	Anthracnose, stem end rot	A	✓✓✓		M3	Protectant

Note that blank fields in the table indicate no information has been provided.
Availability: A = Available via either registration or permit approval; P = Potential i.e. a possible candidate to pursue for registration or permit; P-A = Potential, already approved in the crop for another use;
IPM rating: Grower rating of IPM suitability from ✓ = limited to ✓✓✓ = Good; V= variable, depending on beneficial.
NR= Not required.
WHP = Withholding period

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Mission Produce Supply Chain

Content

1. Mission Produce Background

2. Supply Chain Practices

1. Mission Produce Background

- *Global growing, sourcing (US, Mexico, Peru, Chile, New Zealand) and marketing company (8 ripening facilities in US/Canada, Amsterdam and Shanghai). Markets approx. 22% of global avocado production*
- *Goals:*
  - *Harvest to packed fruit: 24 hours*
  - *Harvest all countries to retail shelf all markets: 30 days*
- *Focus:*
  - *Temperature management*
  - *Soft drops in pack houses*
  - *Minimal handling*
  - *Fruit age*

2. Supply Chain Practices

- ***Harvest***
  - Minimum Dry Matter standard: 23% (industry standard 21.5%)
  - Harvest to pack house same day
  - Keep bins in shade and cover with hessian

2. Supply Chain Practices

- ***Receival***
  - Hydro-cool for 40 minutes. Exit temperature 7 to 10 ° (forced-air cooling is more common in industry)
  - Product transferred to holding cool room at 5 to 7°



2. Supply Chain Practices

- ***Control Centre***
  - ➢ Heart of the pack house
  - ➢ IT-skilled personnel essential

2. Supply Chain Practices

- ***Grading and packing***
  - Facility is refrigerated at approx. 7°
  - “Soft drop” bin tippers used, fruit washed and “blade dryer” used to thoroughly dry fruit, to ensure stickers adhere
  - Optical sorter grades and sizes each fruit (20 images per fruit)
  - Fruit directed to lanes for different packaging, sizes etc
  - Only time fruit is touched is when sorted into cartons or pre-packs put in cartons

2. Supply Chain Practices

- ***Grading and packing***

2. Supply Chain Practices

- ***Storage***
  - Short term storage at 5 to 7°

2. Supply Chain Practices

- ***Transport***
  - Trucks pre-chilled and loading dock pre-sealed
  - Transport temperatures:
    - Export containers: 5˚
    - Domestic road transport: 6˚
  - Product normally shipped to Mission ripening facilities, although some direct to customers, on request

2. Supply Chain Practices

- ***Ripening***
  - ➢ Avocado-specific forced-air ripening facilities; brings product quickly up to temp - depending on fruit condition 15+°
  - ➢ Air pushed, rather than pulled through cartons
  - ➢ Temperature quickly reduced at conclusion of ripening treatment

2. Supply Chain Practices

- ***Retail/Food Service***
  - Stages 2, 3, 4, and 5 offered to customers. Stage 5 normally foodservice only
  - New customers: pre-supply audit undertaken by Mission to bring facilities and practices up to requirements
  - Retail best practice and training: customise resources developed by California Avocado Commission (Good relationship between Commission, shippers and retailers)

2. Supply Chain Practices

- ***Balancing Supply and Demand***
  - Even with sophisticated planning information, still a challenge to balance supply and demand
  - Suppliers work well in advance with retailers to plan programs, especially high demand events, such as 4th July and Superbowl
  - When there are shortages, communication with customers is critical
  - Crop forecasting also a challenge – company Field representatives play a key role

applied horticultural research

Avocado supply chain quality improvement (AV15010)

Jenny Ekman

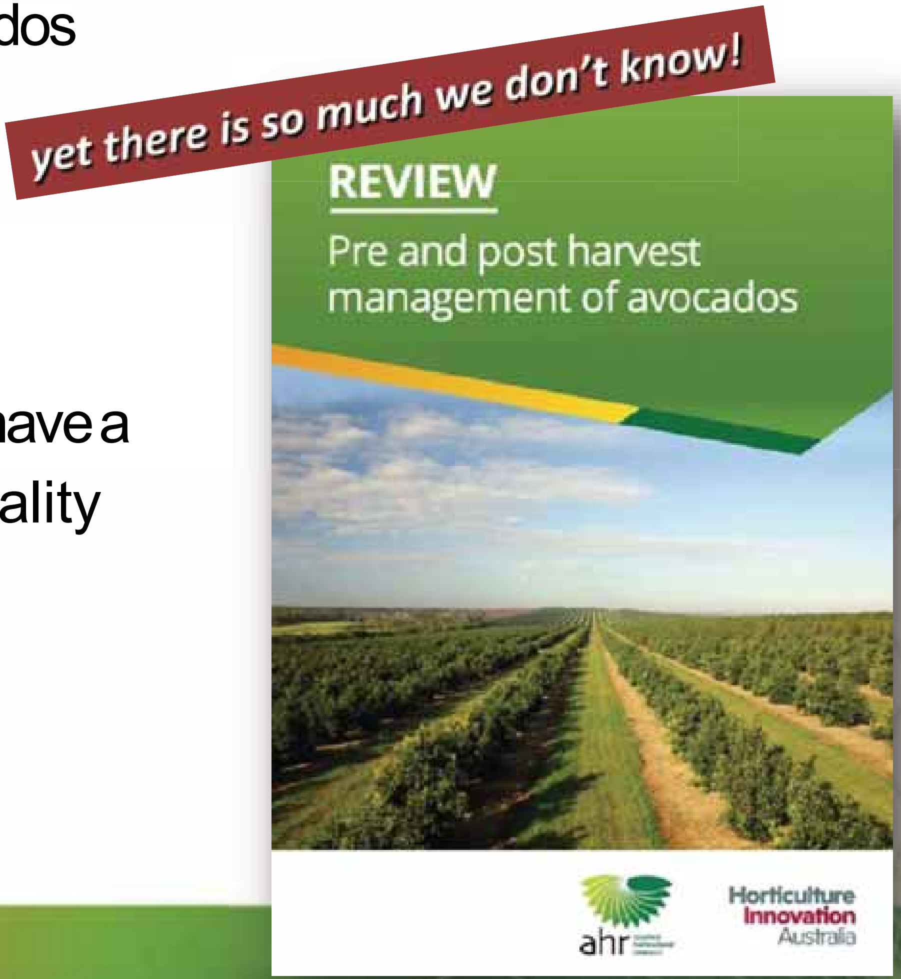
Project objectives

Objectives

1. Increase the adoption of best practice in cool chain management and postharvest handling across all sectors of Australian avocado supply chains from orchard to retail
2. Reduce the incidence of body rots and other quality defects in avocado fruit (25% → 10%)
3. Increase the awareness across the supply chain of factors that predispose fruit to quality defects

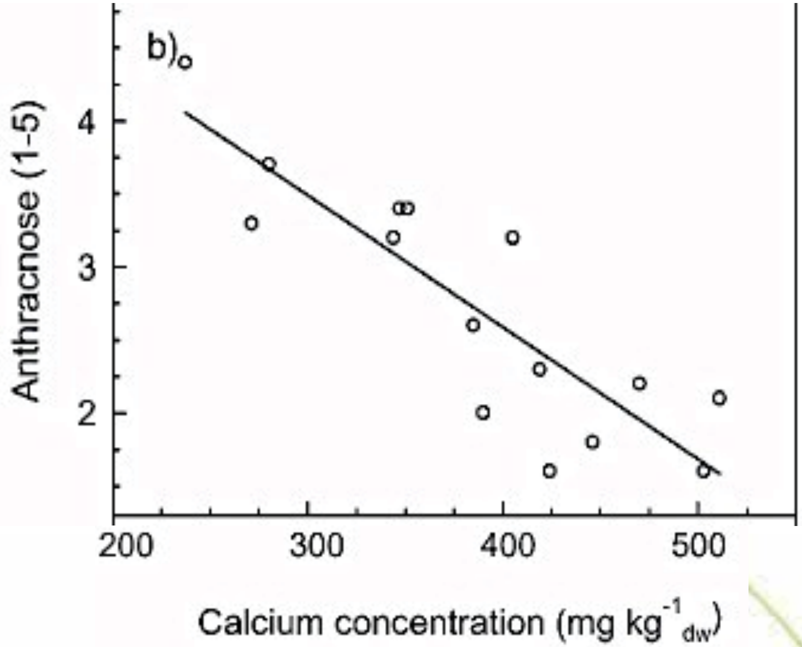
Pre- and postharvest review

- Much has been written about pre- and postharvest management of avocados
  - 8,750 papers on CAB
  - 150,000 results on Google Scholar
- Completed a 70 page review
- Both pre- and postharvest factors have a significant effect on postharvest quality



Pre-harvest: Nutrition

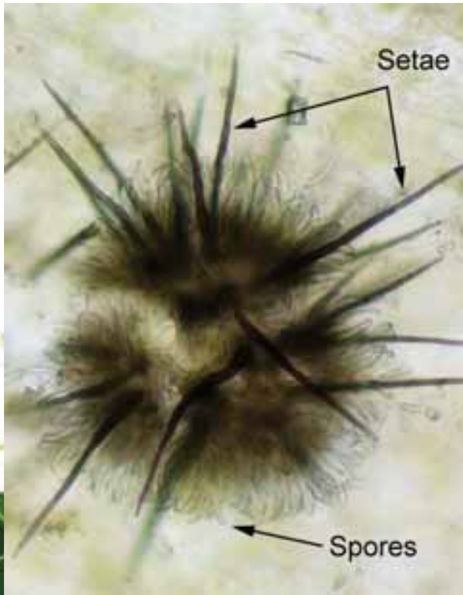
- Lots of research…
- High calcium in fruit
  - Reduces disease
  - Reduces disorders
- BUT there is no reliable way to ***increase calcium in fruit***
- Excess nitrogen
  - Increases disorders
  - ***Reduces fruit calcium***
- Other nutrients variable



From Hofman et al, 2002

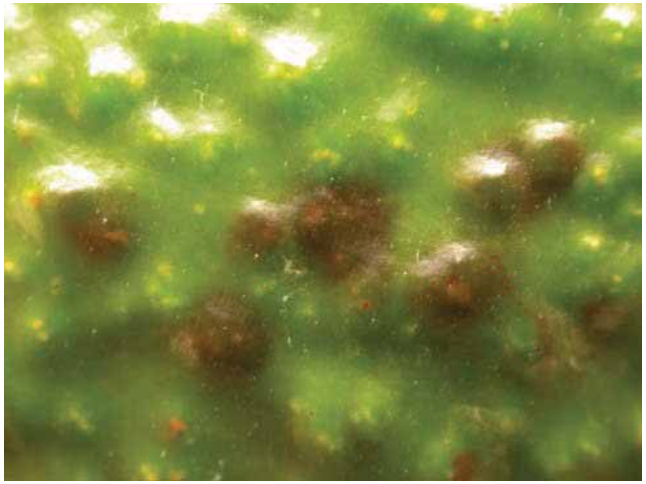
Pre-harvest: Fungicides

- Application of fungicides ***at flowering*** is critical
  - Suppress spore germination and spread into young fruitlets
- Continued sprays through fruit development prevent inoculum building up in the orchard.
  - Strobilurins (Amistar, Flint) alternated with copper sprays 1:2
  - Red copper oxide has best adhesion in rainy weather
- Disease resistance due to *anti-fungal dienes* in fruit
  - Increased by plant cytokinins, SARs (phosphorus acid)
- Hygiene and pest management limit disease spread



Harvest

- Fruit should not be picked wet (if possible)
  - **Rain and irrigation = swollen lenticels = peel damage = rots**



From Pak et al, 2003

- Fruit can be much hotter (~10^{o}C) than the surrounding air

Harvest: Snap v Clip?

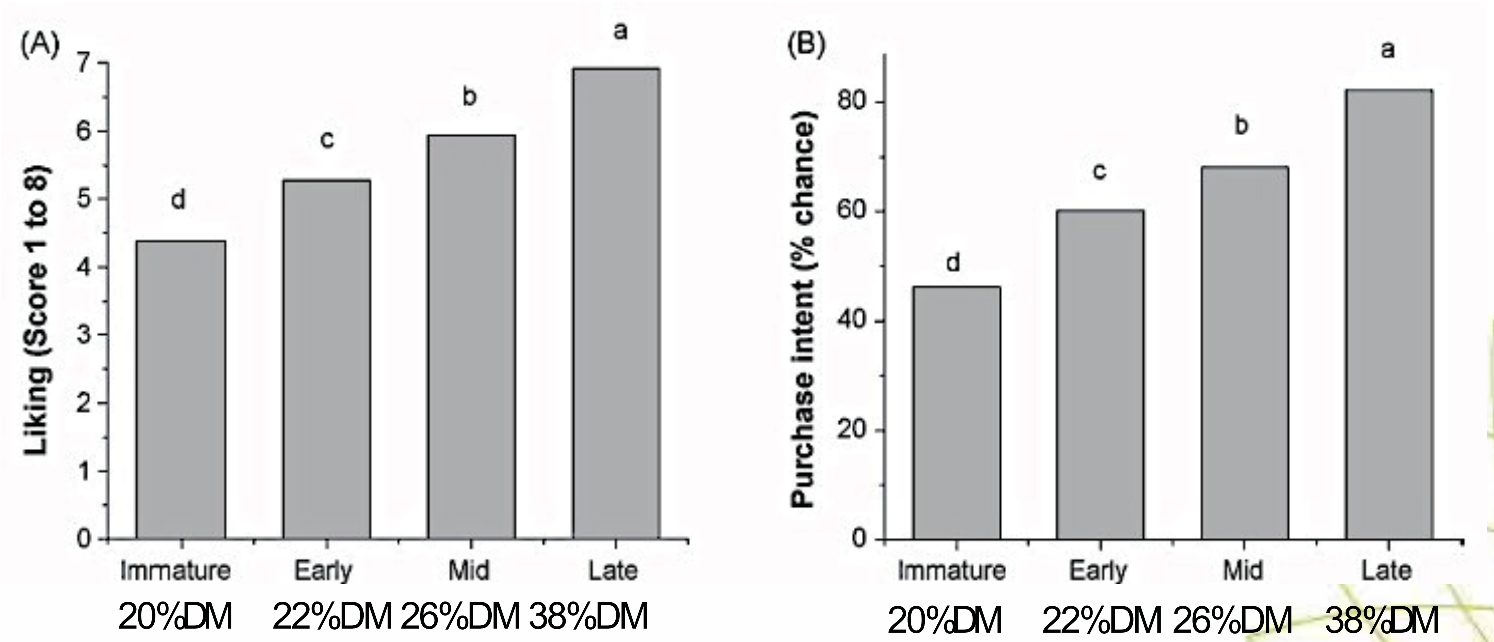
- Snapping vs clipping
  - NZ and South Africa clip
  - Snapping is quicker
  - Shepard always clipped (?)
- Willingham (AV01004) recommendation: Avocados can be snapped if
  - Trees not stressed
  - Fruit is not immature OR over mature (23-29% DM)
  - Fruit not harvested damp
  - Fruit not treated with Sunny (Uniconazole PGR)

Economic viability: Clipping reduces rots, doubles cost

Fruit maturity

- Maturity (dry matter) at harvest is critical
- ***Low dry matter*** → slow ripening, poor texture and flavour, increased rots, vascular browning.

From Gamble et al, 2010



Fruit maturity

- ***High dry matter*** → happy consumers, reduced chilling sensitivity and faster ripening
- ***BUT*** rots, grey flesh and vascular browning may increase.

Dry matter varies within orchards, between trees and within trees

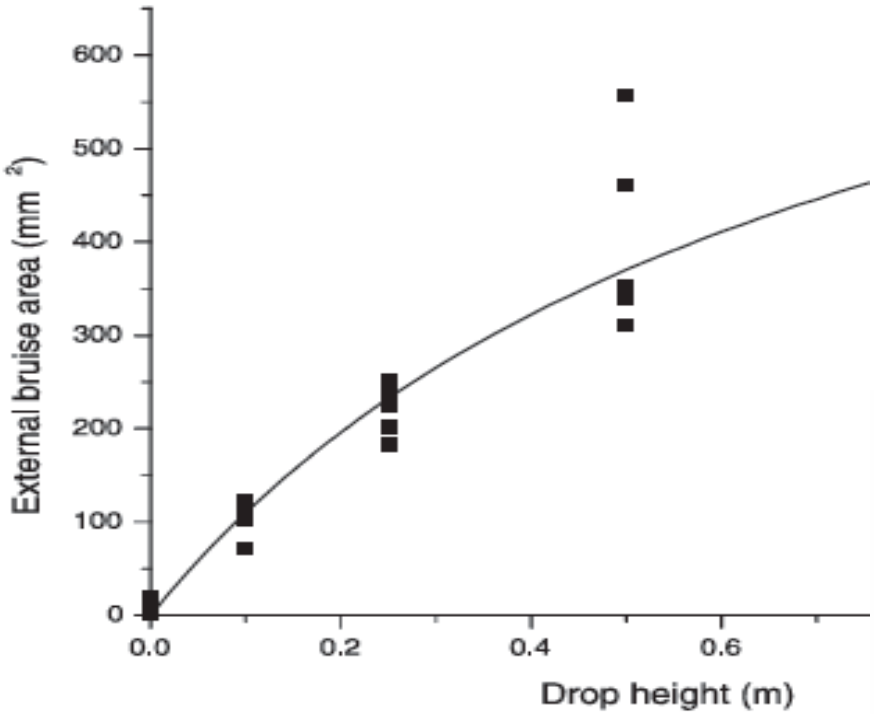
Less variable quality at retail →

increased sales

Should industry consider NIR grading ??

Bruising: farm and packhouse

- Hard avocados are susceptible to bruising

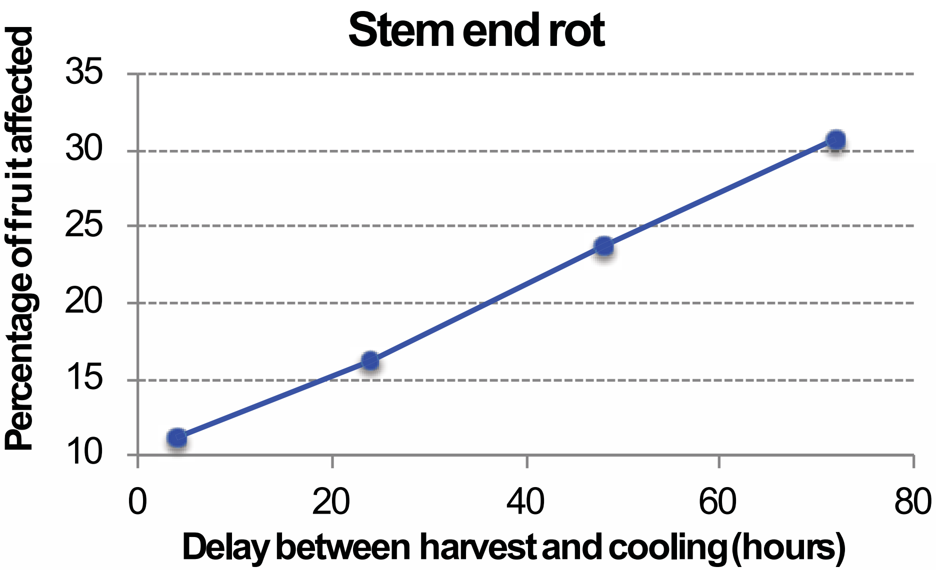


From Mandemaker et al, 2006.

ALL fruit drops should be minimised

Pre-cooling

- Avocados don't ripen on the tree because of the "***tree factor***"
  - The tree factor degradation affected by temperature + time
- ***Variable temperature → variable ripeness at retail***

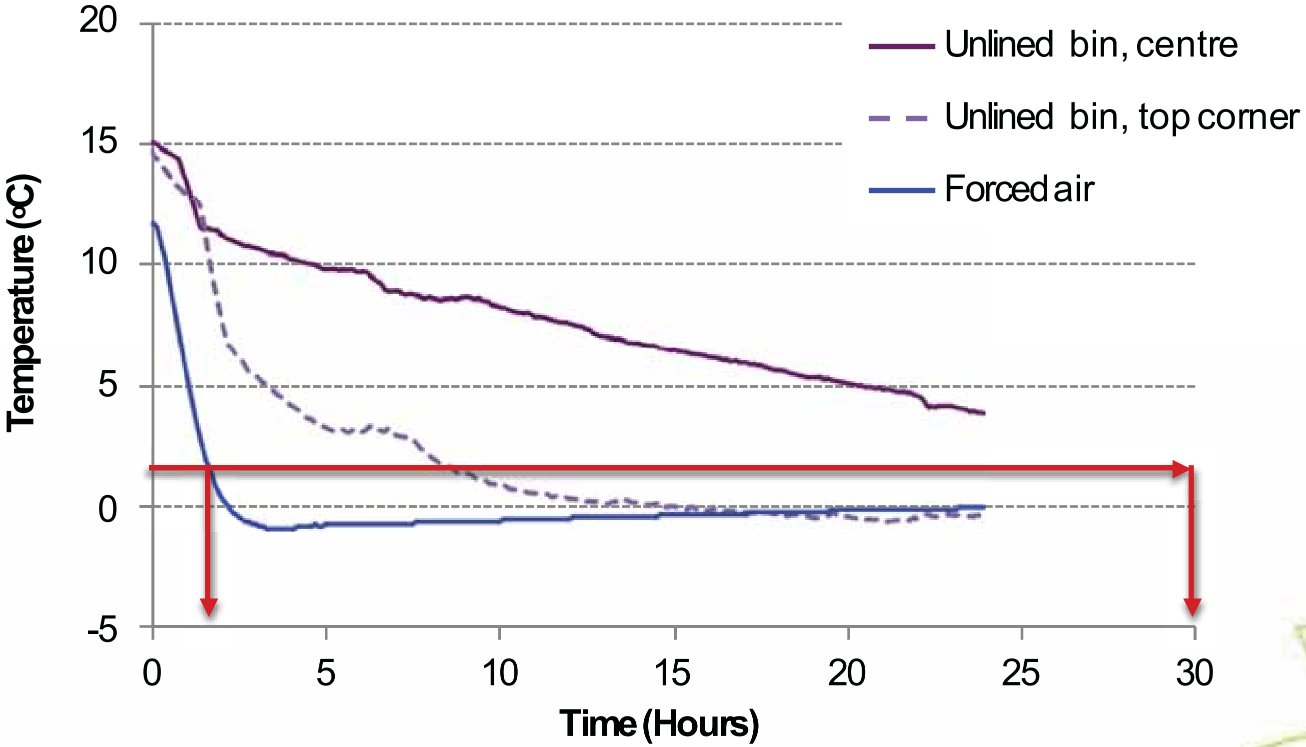


Fruit that stays warm after harvest is more likely to develop rots and internal discolouration, lose weight, ripen faster

Temperature variability in bins

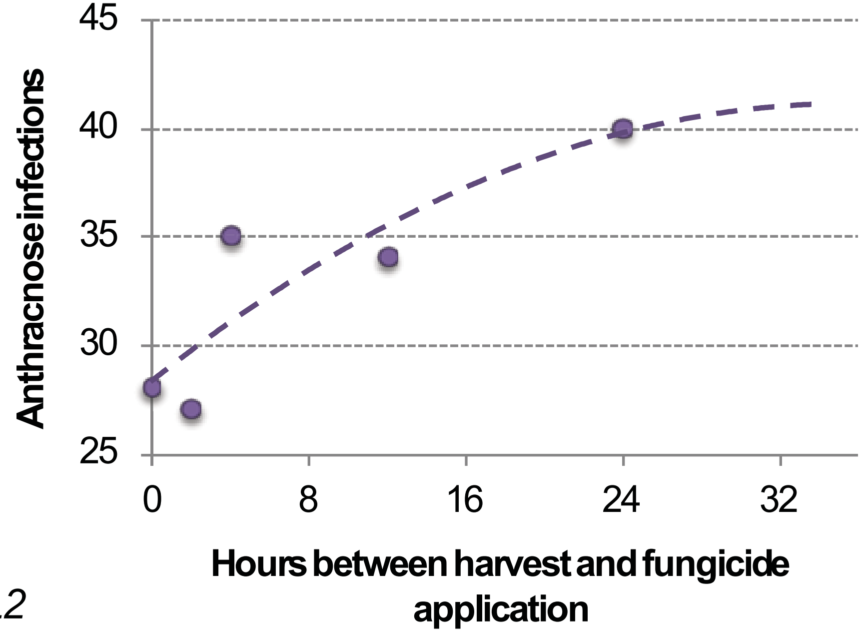
How warm are avocados in the centre of bins?

Temperature variability → more variability in ripeness



Postharvest fungicides

- ***Postharvest fungicides can reduce rots by approx 20 to 50%***
  - If this is from 90% to 70% so what?
  - Timing likely to be critical for infections at harvest eg SER
  - Less effect on pre-harvest infections
  - Results with SARs (systemic acquired disappointing
  - Thyme oil?



Derived from Everett, 2012

Potential postharvest treatments

- ***Surface coatings can reduce moisture loss and improve both appearance and shelf life*.**
  - Surface coatings modify the internal atmosphere
  - Add fungicidal compound (thyme oil?) for improved effect
  - Carnauba wax reduced chilling sensitivity
- ***SmartFresh – 1-MCP***
  - Delays ripening, allowing extended low temperature storage (42d @ 5°C)
  - Reduces chilling sensitivity
  - Used by South Africa
  - Variable ripening after treatment is the biggest issue

SmartFresh

4 weeks

7 weeks

4 or 7 weeks at 5.5°C +1d @20°C. *From Woolf et al., 2005*

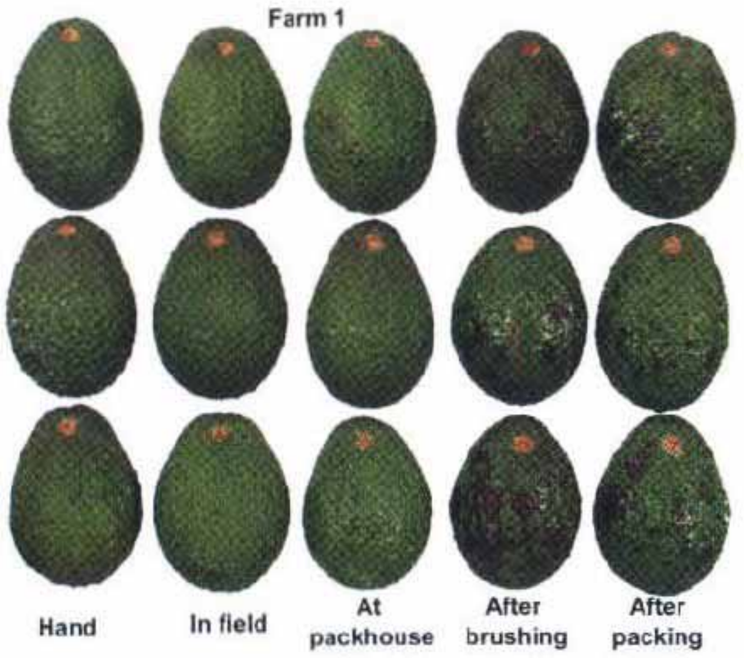
Potential postharvest treatments…

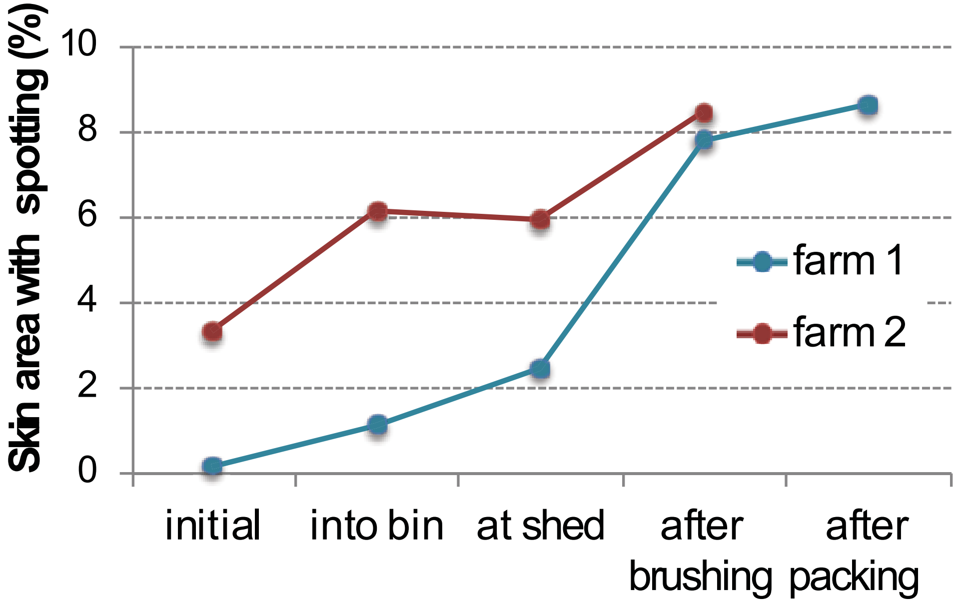
- ***Heat treatment***
  - May protect against chilling injury during cold disinfestation
  - Relatively narrow band of time / temperature combinations
- ***Low temperature conditioning***
  - Staged cooling over several days or weeks
  - Results variable!
    - Hofman 2010
    - Marques et al 2010

Woolf, 1997

Grading and packing

- Fruit may need washing, but should not be packed wet
- Brushes on packing lines can jostle fruit
  - Increase lenticel damage, spotting
- Dropped trays = bruised fruit
- Packing fruit while cold reduces bruising





Hofman, 2005

Grading and packing

- ***Sorting using Near Infrared Spectroscopy (NIR)***
  - Segregate fruit based on dry matter → ***less variability in ripeness***
  - Detects bruising and internal rots → ***less defects at retail***
  - **In-line sorting could reduce variable ripening**

James Cook University

Grading and packing – key points

- ***Uneven temperature management*** likely contributes to variable ripening and quality issues
  - **Improve pre-cooling**
  - **Reduce harvest to pack times**
- ***ARE*** Postharvest fungicides applied more than 24h after harvest a waste of money?
- ***Surface coatings*** are not just a pretty face
- ***Optimise packing lines*** to minimise bruising and skin damage

Cooling and storage

- ***Warm fruit loses moisture. Fast cooling after packing is essential*.**

> *Product can deteriorate as much in 1 hour at 25°C*
> *as in 1 week at 1°C*

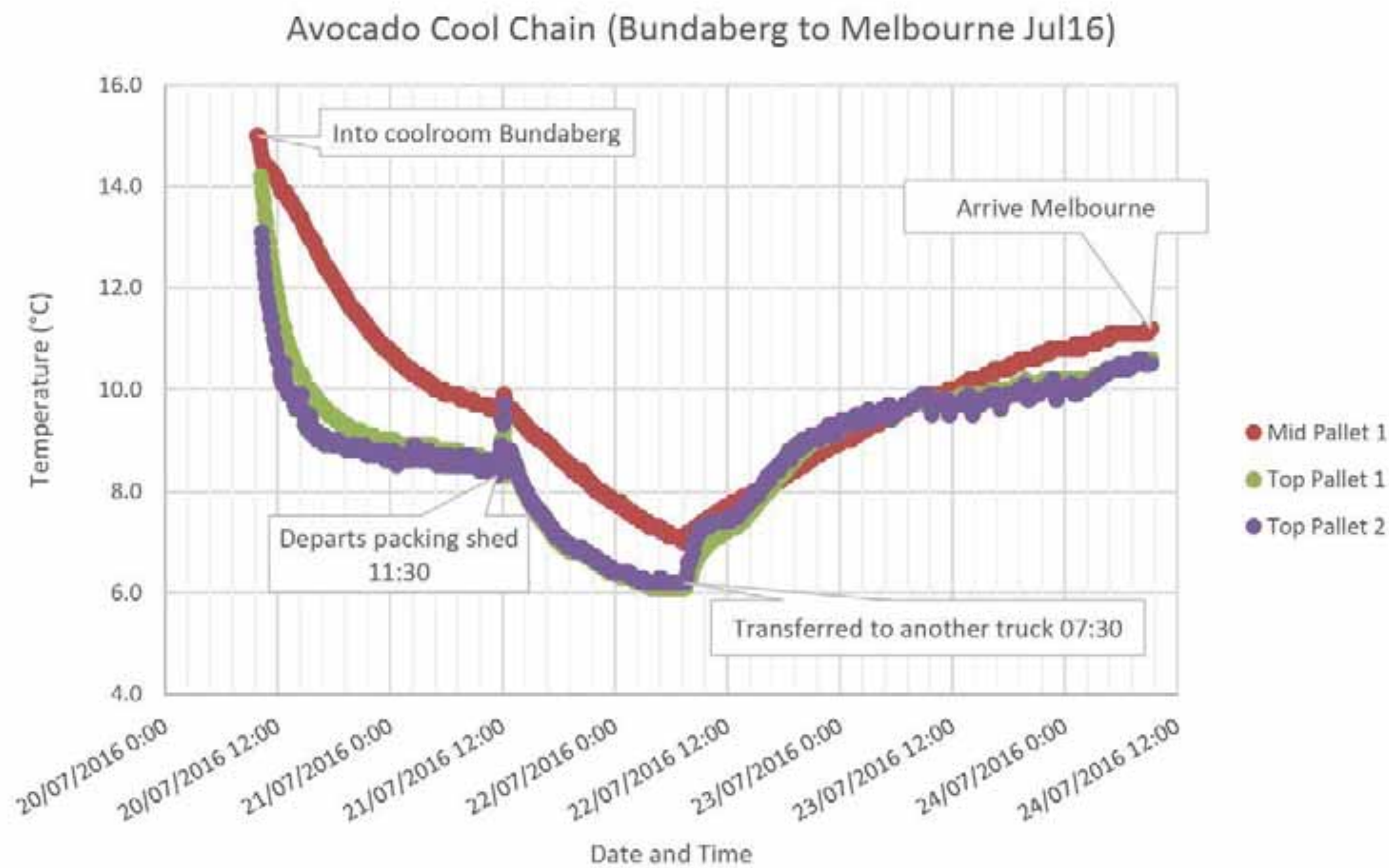
- ***Delays in cooling allow fruit to start ripening.***
  - Increased chilling sensitivity
  - Increased rots
  - Variable ripeness at retail
- ***Room cooling is very slow***, 0.5°C per hour
- ***Forced air cooling is 3 to 8 x faster***, min. 2°C per hour

Cooling and storage

Breaks in the cold chain can have a major impact on quality

Break of only 5 hours can increase rots

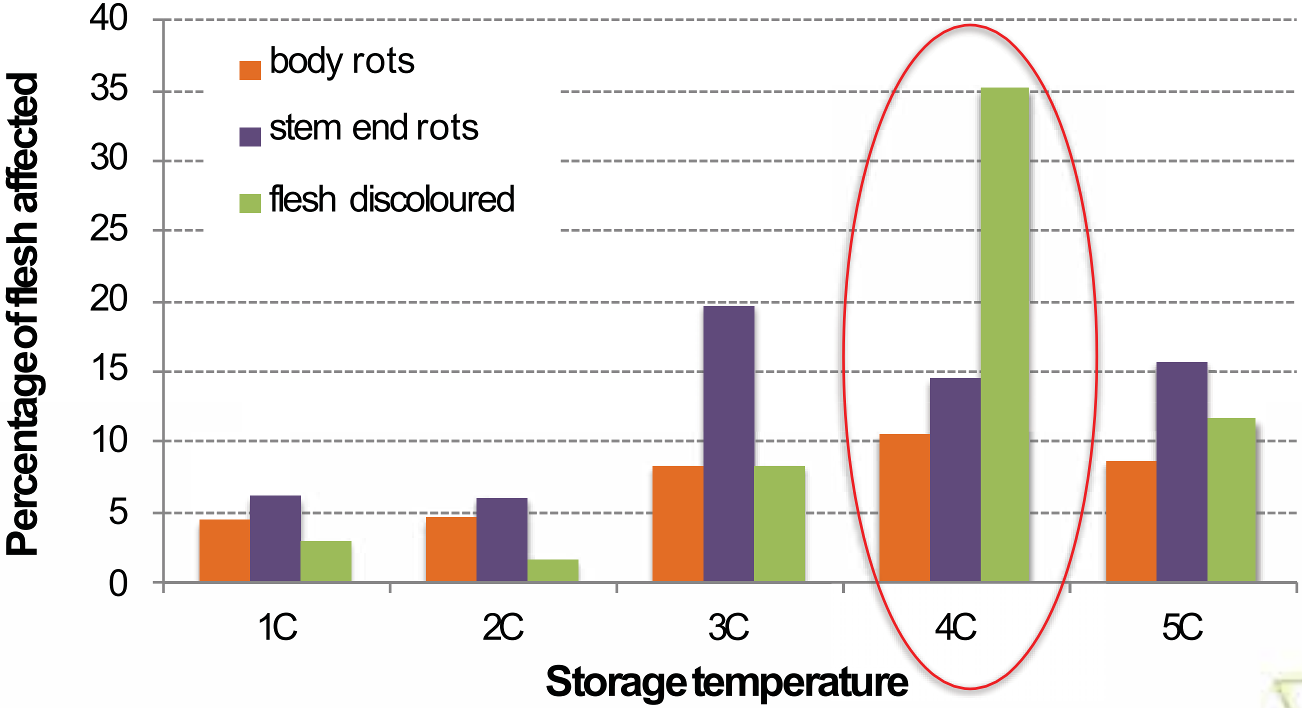
The longer that fruit has been stored, the bigger the effect of a break



Cooling and storage

- ***Concept of Killing Zone***

Derived from Hofman et al, 2010



Pre-conditioned at 6 °C for 3 days, then stored at 1 to 5 °C for 31 days, ripened at 20 °C

Cooling and storage

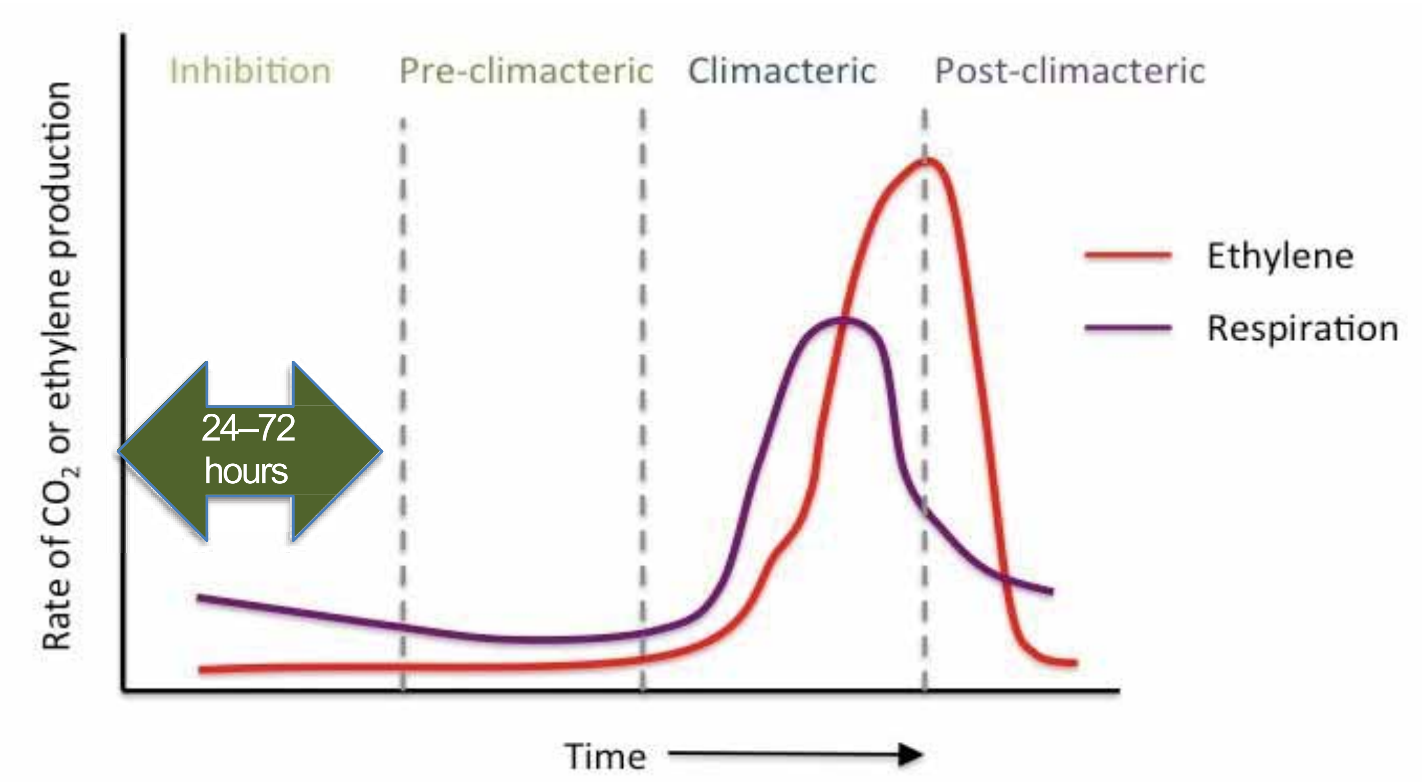
- **Removing ethylene** from the storage environment can increase storage life
- **Controlled atmospheres** can also improve storage life
- **Fruit should not be more than 30 days old when ripe**
  - Anti-fungal compounds in fruit decline during storage
  - Stem end rots advance during storage
  - After 4 weeks incidence and severity of rots markedly increases

Cooling and storage – key points

- HOW LONG DOES IT TAKE FRUIT IN A BIN TO COOL?
- HOW LONG CAN FRUIT STAY WARM WITHOUT AFFECTING QUALITY?
- ***Ripening initiated in storage –>*** increased variability and chill damage
- ***Australian supply chains can be variable***
  - ***Poor temperature control*** → increased variability and fruit rots
  - ***Ethylene monitoring / removal***
  - *TRANSPORT AT 5^{o}C?*

Ripening

Once ripening starts, it is unstoppable



Ripening

- ***Dry Matter*** content critical to ripening time
- ***High temperatures*** increase the rate of ripening but reduce quality
- ***Ripened fruit need to be held to allow for distribution and retail***
  - Rubbery: store at 2 °C
  - Soft: store at 5–8 °C

Rubbery-sprung Sprung-softening Softening-firm

Fruit quality after 7 days at 2 °C

Ripening – key points

- ***The ripening room is not a hospital***
- Fruit may be ripened at higher temperatures to meet supply chain requirements ***– but this will reduce quality at retail***
  - Are wholesalers monitoring ethylene and CO_2 during ripening?
  - Are rooms well temperature managed?

Key supply chain issues

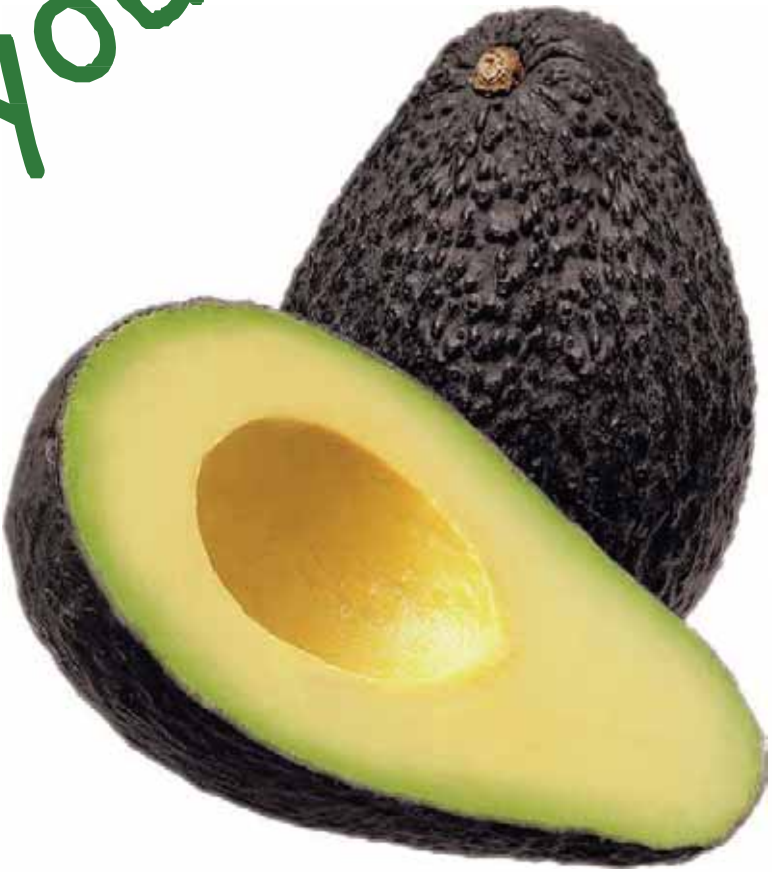
- ***Variability in ripeness***
  - Temperature management, from harvest to ripening
  - Dry Matter variability
  - Ripener skills
- ***Rots, bruises and other internal issues***
  - Handling from harvest to retail
  - Pre-harvest fungicide management eg applications during flowering
  - Postharvest fungicides – are they effective?
  - Cooling after harvest and packing
  - Temperature management during transport and storage
  - Fruit age (Erratic ordering / top ups)

Best practice resources needed

- ***Growing***
  - Printed growing guide – all the online best-practice resource
  - Include pre-harvest management of disease
- ***Cool chain*** (harvest to wholesale/ripening)
  - Temperature management and monitoring through the coolchain
  - Management of fruit age
  - Real world examples of quality issues that result from poor practice
- ***Critical control point resource*** – QDAF
  - Hazards, causes, controls
  - Problem solver
  - Orchard to retail

Other?

Thank you



Avocado supply chain quality improvement (AV15010)

Jenny Ekman & Adam Goldwater

Project objectives

1. Increase adoption of best practice

2. Reduce the incidence of quality defects

3. Increase awareness of factors that predispose fruit to quality defects

Pre- and postharvest review

- LOTS has been written about pre- and postharvest management of avocados
  - 8,750 papers on CAB
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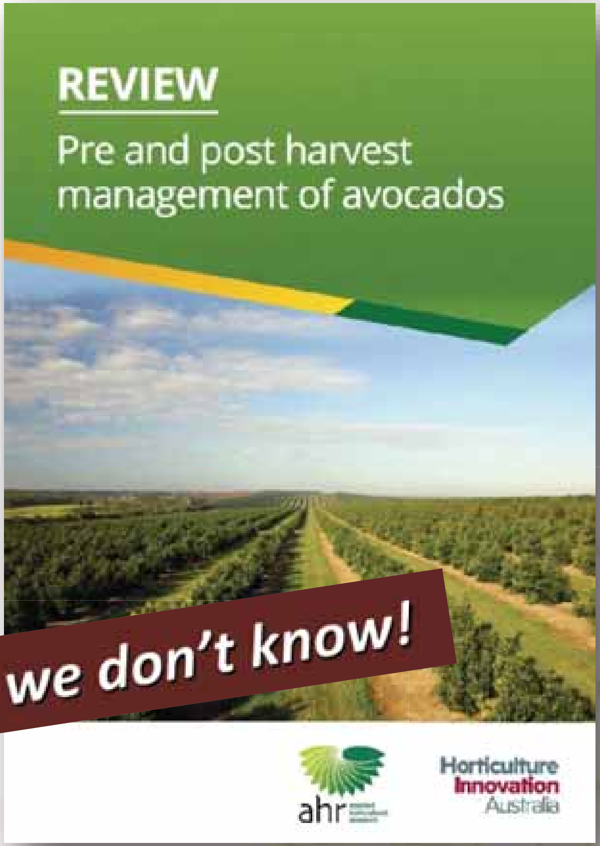
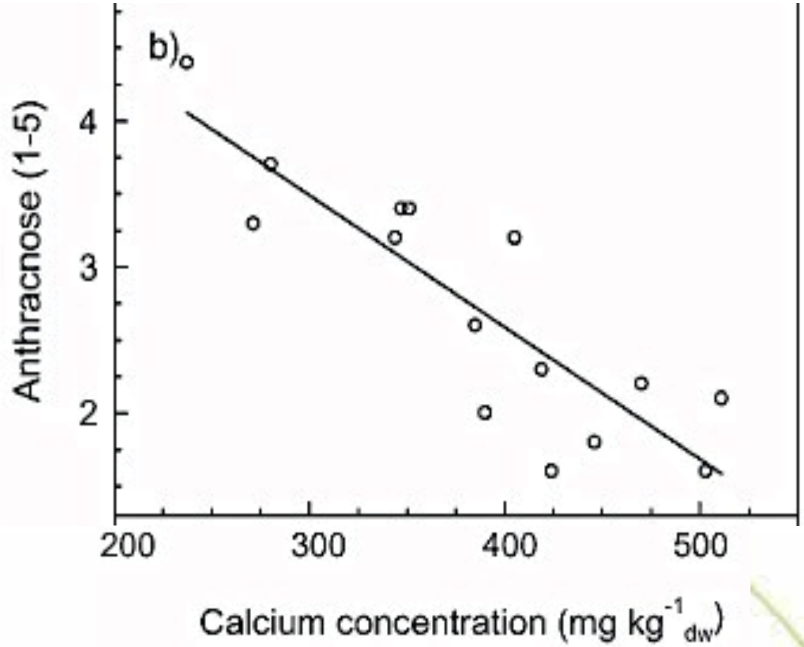
- Both pre- and postharvest factors have a significant effect on postharvest quality



yet there is so much we don't know!

Pre-harvest: Nutrition

- Many papers….
- High calcium in fruit
  - Reduces disease
  - Reduces disorders
- BUT there is no reliable way to ***increase calcium in fruit***
- Excess nitrogen
  - Increases disorders and ***reduces calcium***

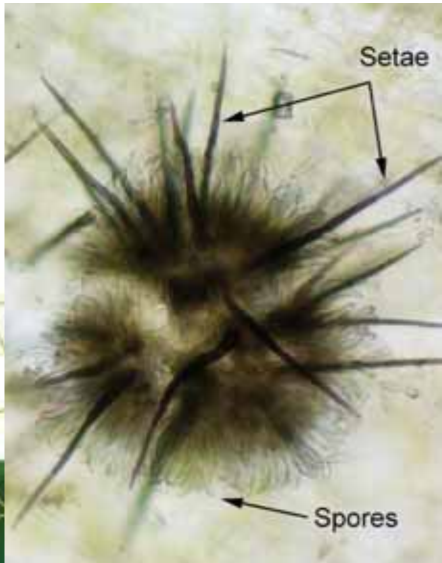


From Hofman et al, 2002

MEASURING: Calcium is highest in mature fruits from indeterminate shoots, at the stem end and on the sunny side of fruit

Pre-harvest: Fungicides

- Disease resistance due to ***anti-fungal dienes*** in fruit
  - Increased by plant cytokinins, SARs (phosphorus acid)
  - Disappear over time (~25 days)
- Application of fungicides ***at flowering*** is critical
  - Suppress spore germination and spread into young fruitlets
- Hygiene and pest management limit disease spread



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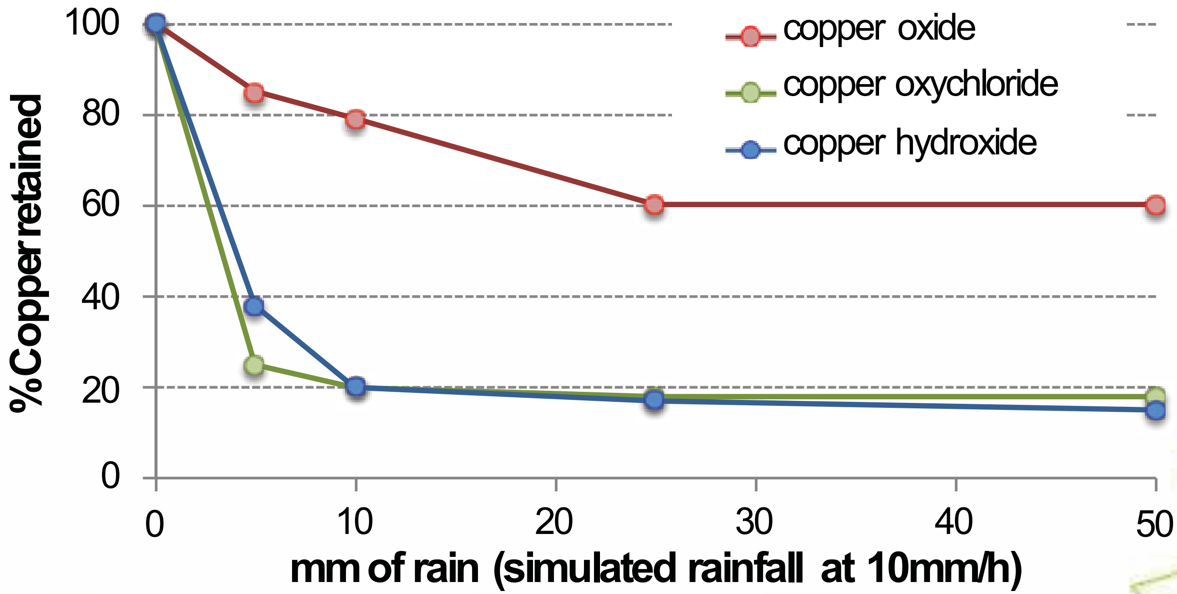
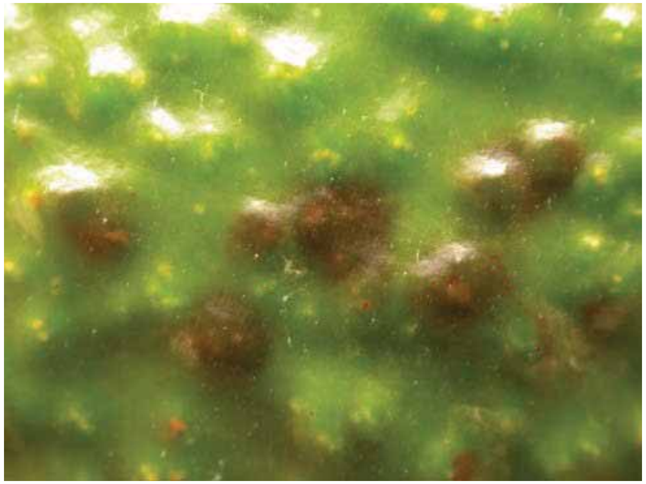


Centrilab, Holland

Harvest

- Fruit should not be picked wet (if possible)
  - **Rain / irrigation / condensation = swollen lenticels = peel damage = rots**



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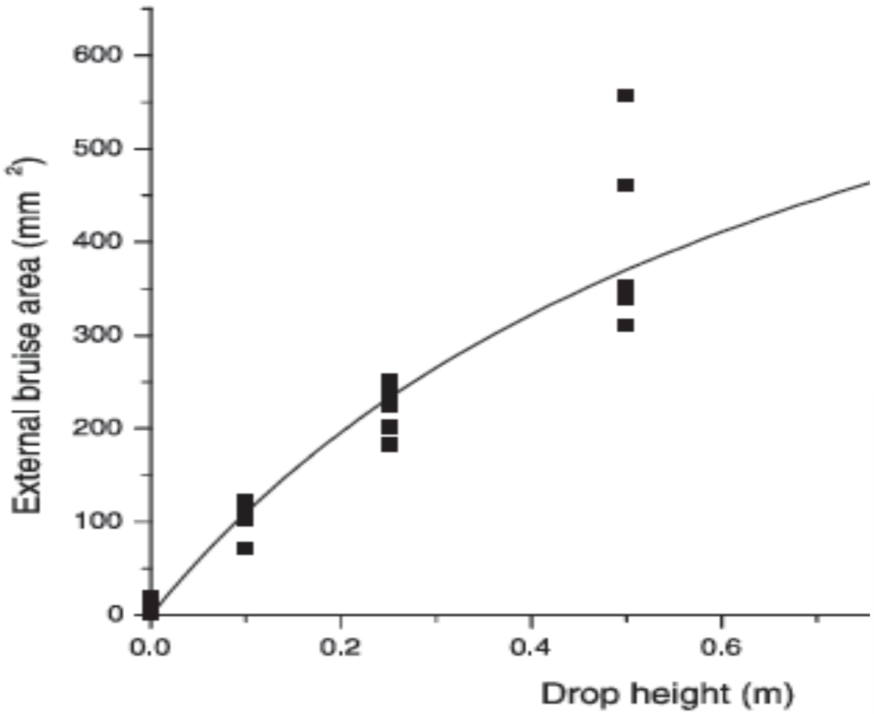
Bruising: farm and packhouse

- Hard avocados are susceptible to bruising



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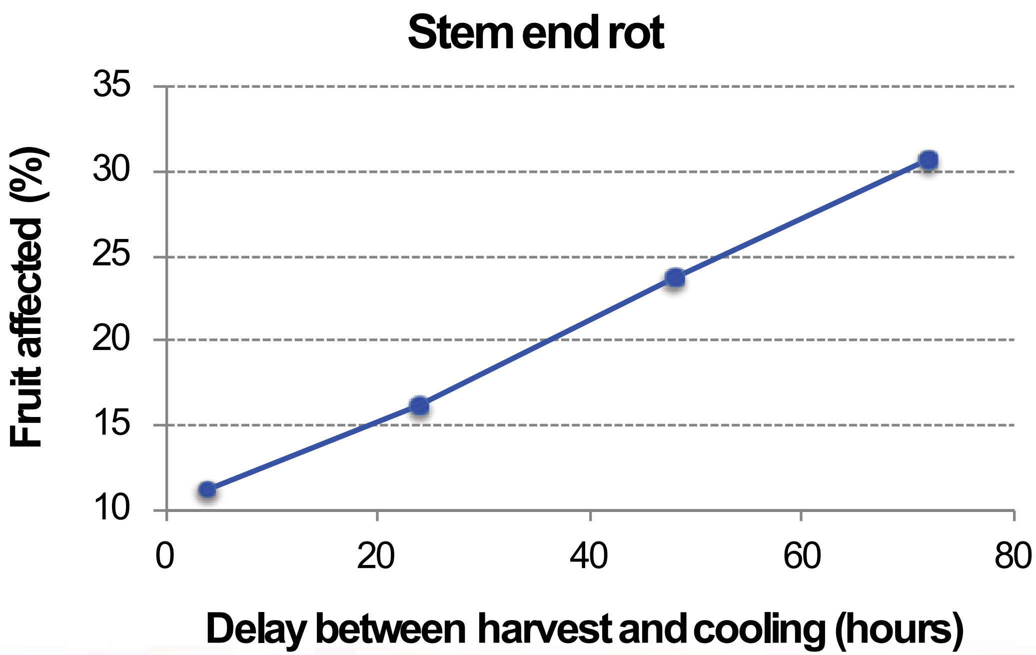
- ***Variable temperature → variable ripeness at retail***



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Temperature variability in bins

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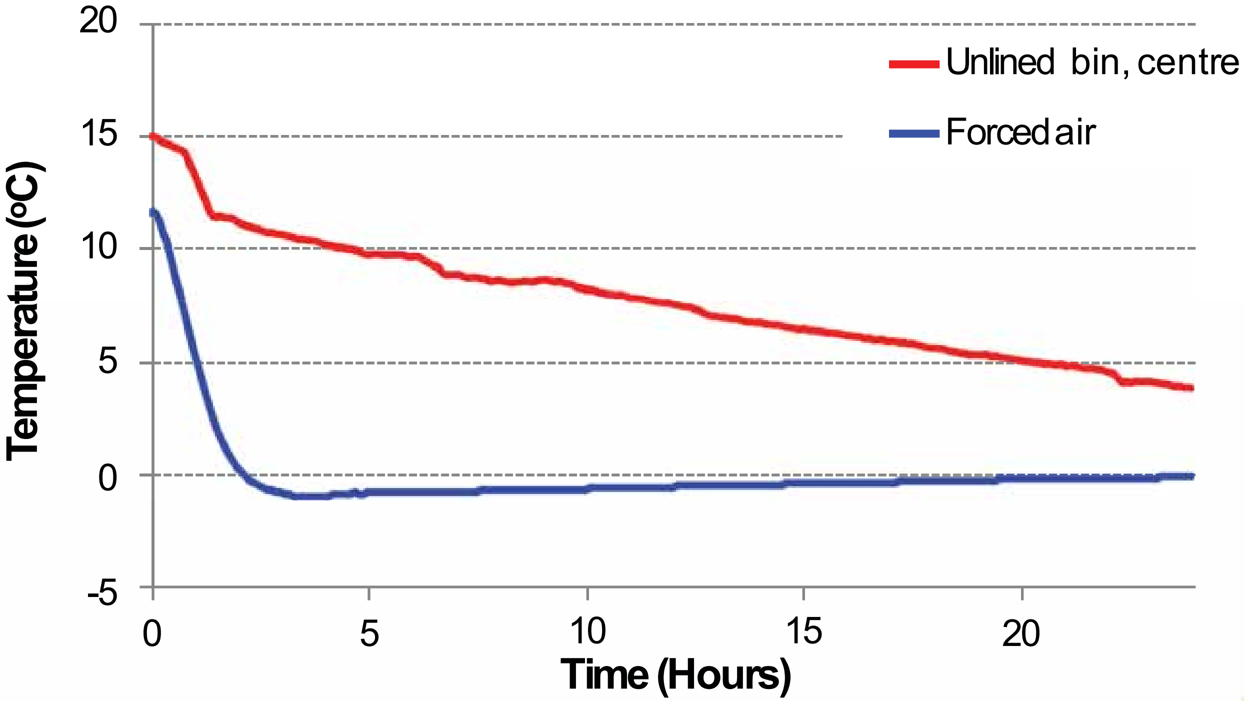
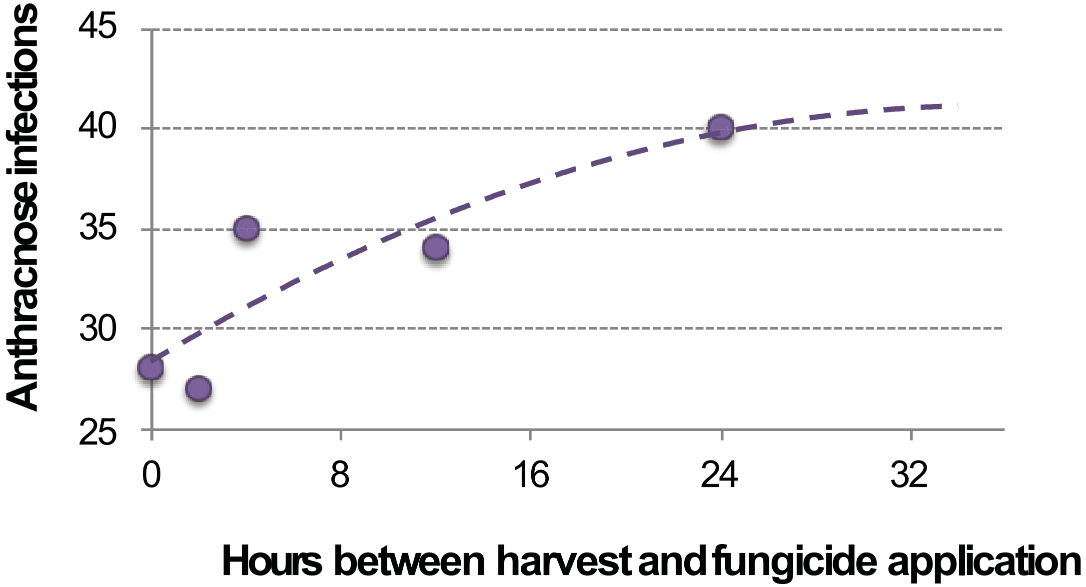


Worse if the cold room is overloaded

Postharvest fungicides

- ***Postharvest fungicides <u>can</u> reduce rots by approx 20 to 50%***
  - Timing likely to be critical for infections at harvest eg SER
  - Less effect on pre-harvest infections
  - Results with SARs (systemic acquired resistance) so far disappointing
  - Thyme oil?



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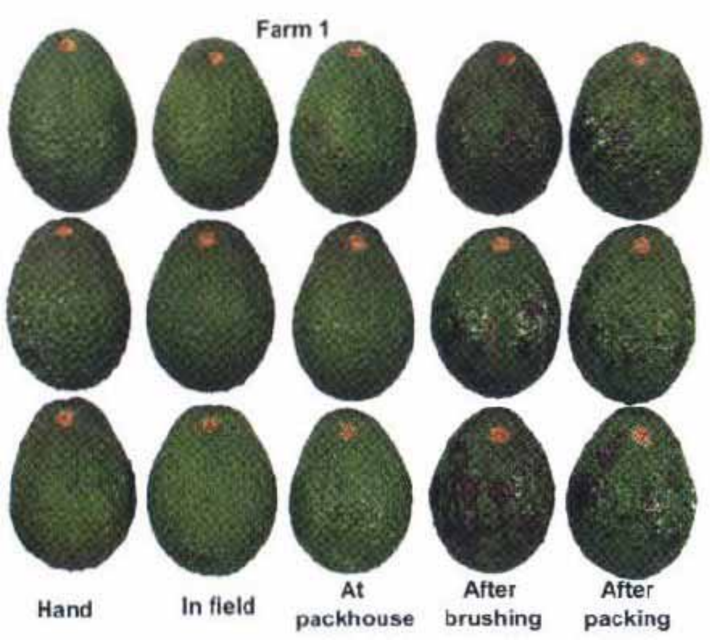
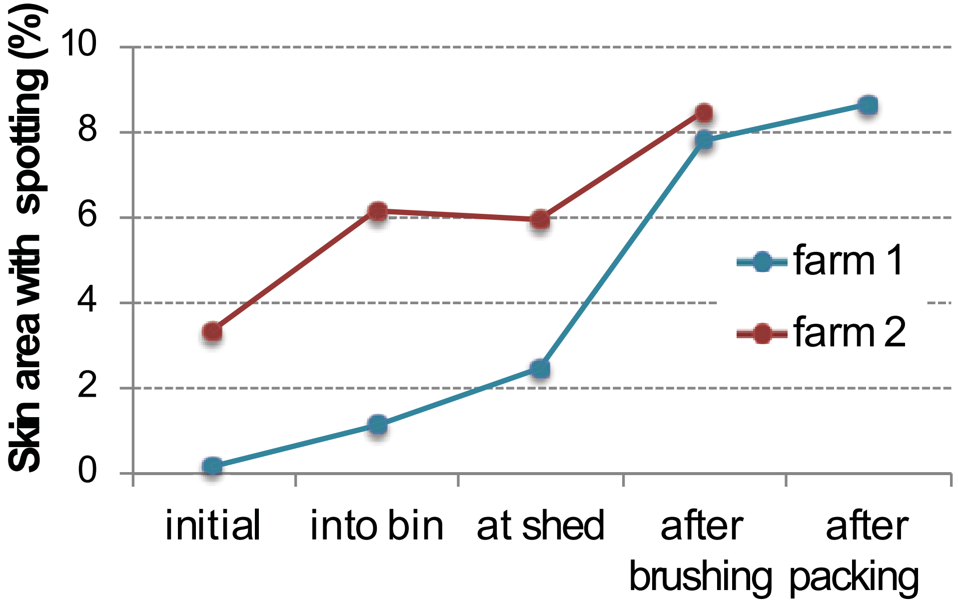
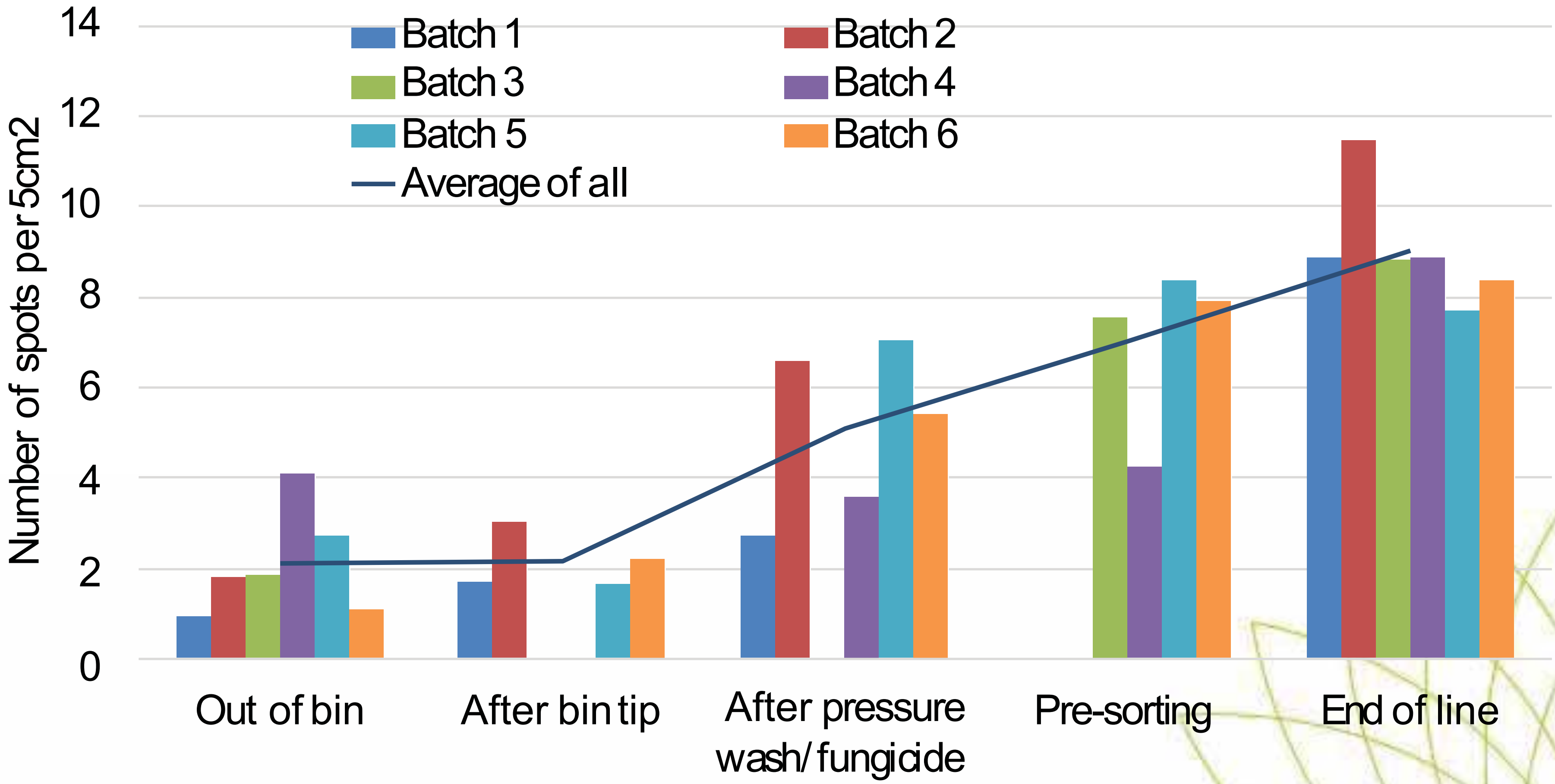




Hofman, 2005

Lenticel damage on the packing line



Grading and packing

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  - Segregate fruit based on dry matter → ***less variability in ripeness***
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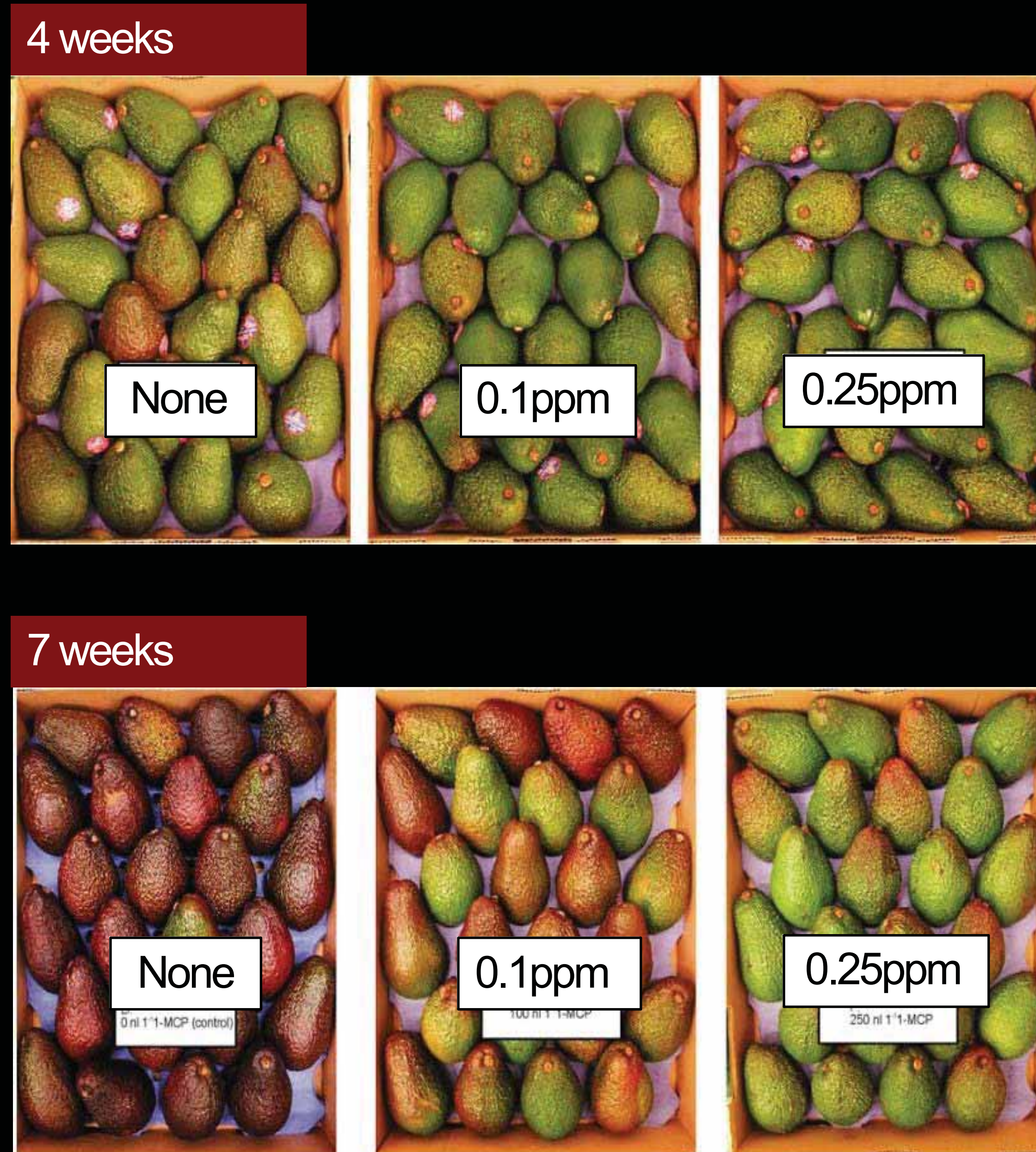
  - **In-line sorting could reduce variable ripening**

James Cook University

SmartFresh (1-MCP)

- Delays ripening
- Extends low temperature storage (42d @5°C)
- Reduces chilling sensitivity
- Used by South Africa
- Variable ripening is the biggest issue



4 or 7 weeks at 5.5°C +1d @20°C. *From Woolf et al., 2005*

Cooling and storage

- ***Warm fruit loses moisture. Fast cooling after packing is essential.***

Product can deteriorate as much in 1 hour at 25°C as in 1 week at 1°C

- ***Delays in cooling allow fruit to start ripening.***
  - Increased chilling sensitivity
  - Increased rots
  - Variable ripeness at retail
- ***Room cooling is very slow***, 0.5°C per hour
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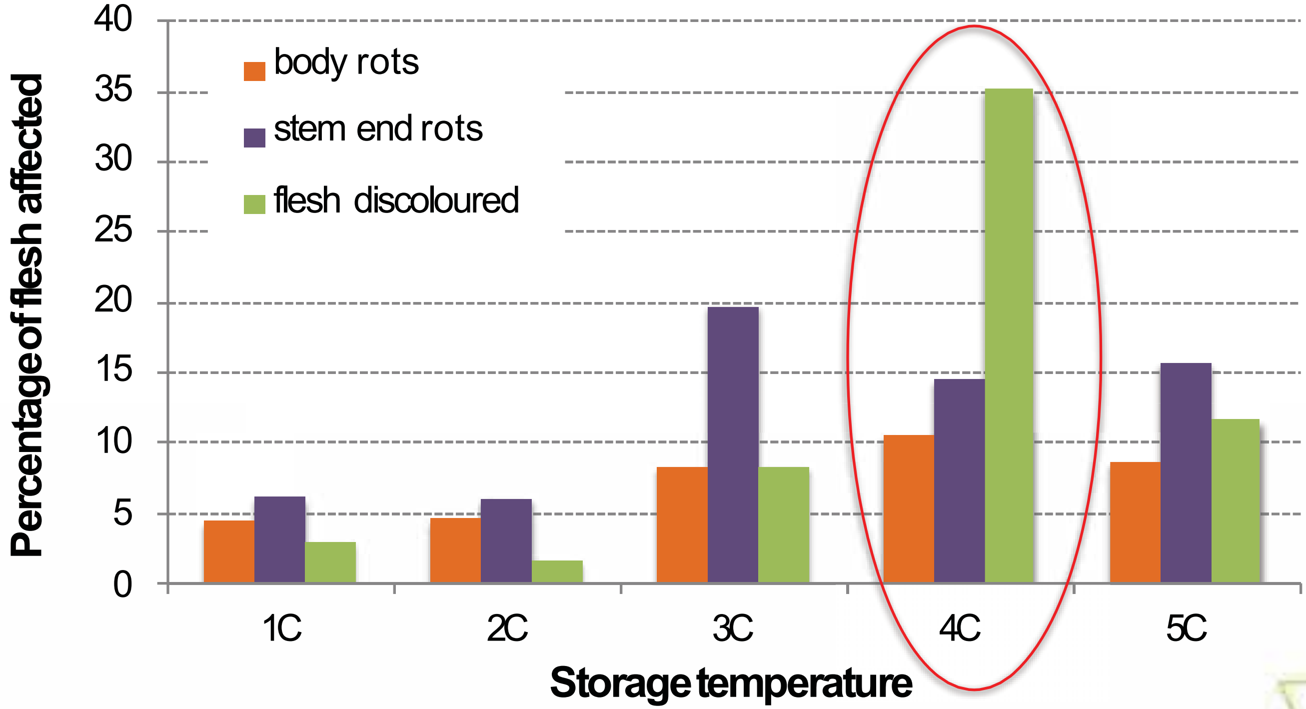
Cooling and storage

- ***Concept of Killing Zone***

Derived from Hofman et al, 2010



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Ripening

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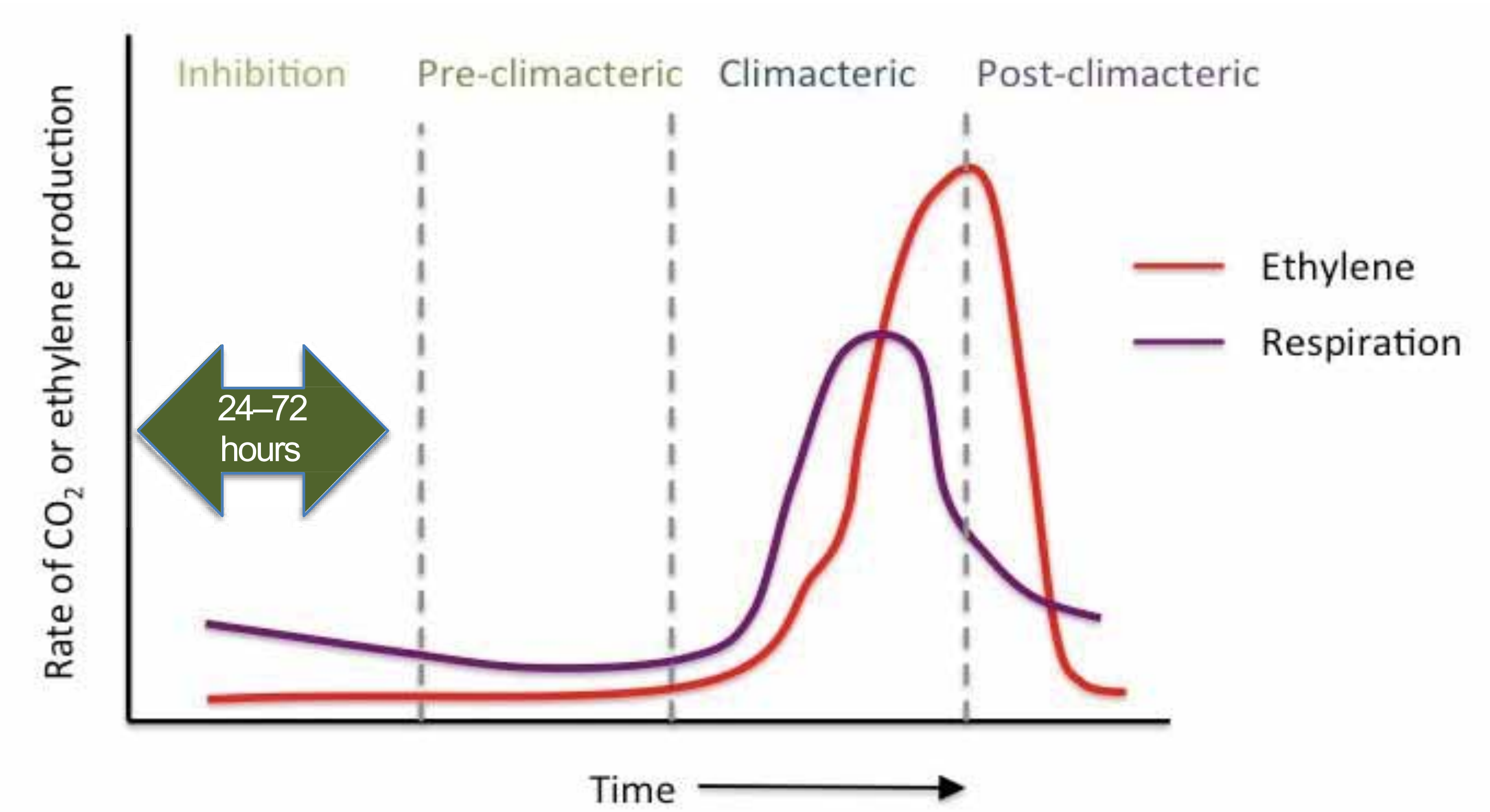


Ripening

- ***Dry Matter*** content critical to ripening time
- ***High temperatures*** increase the rate of ripening but reduce quality
- ***Ripened fruit need to be held to allow for distribution and retail***
  - Rubbery: store at 2 °C
  - Soft: store at 5–8 °C

Rubbery-sprung

Sprung-softening

Softening-firm

Fruit quality after 7 days at 2 °C


Fresh Mushrooms
Now in Season
GROWN & PACKED BY
COUNT
14 20 25 32
16 22 28
18 23 30
CLASS 1
Locally Grown
VARIETY
PLEASE KEEP COOL
AUSTRALIAN MUSHROOMS
FRESH MUSHROOMS
KEEP ME COOL
Wild Rocket
Rootz

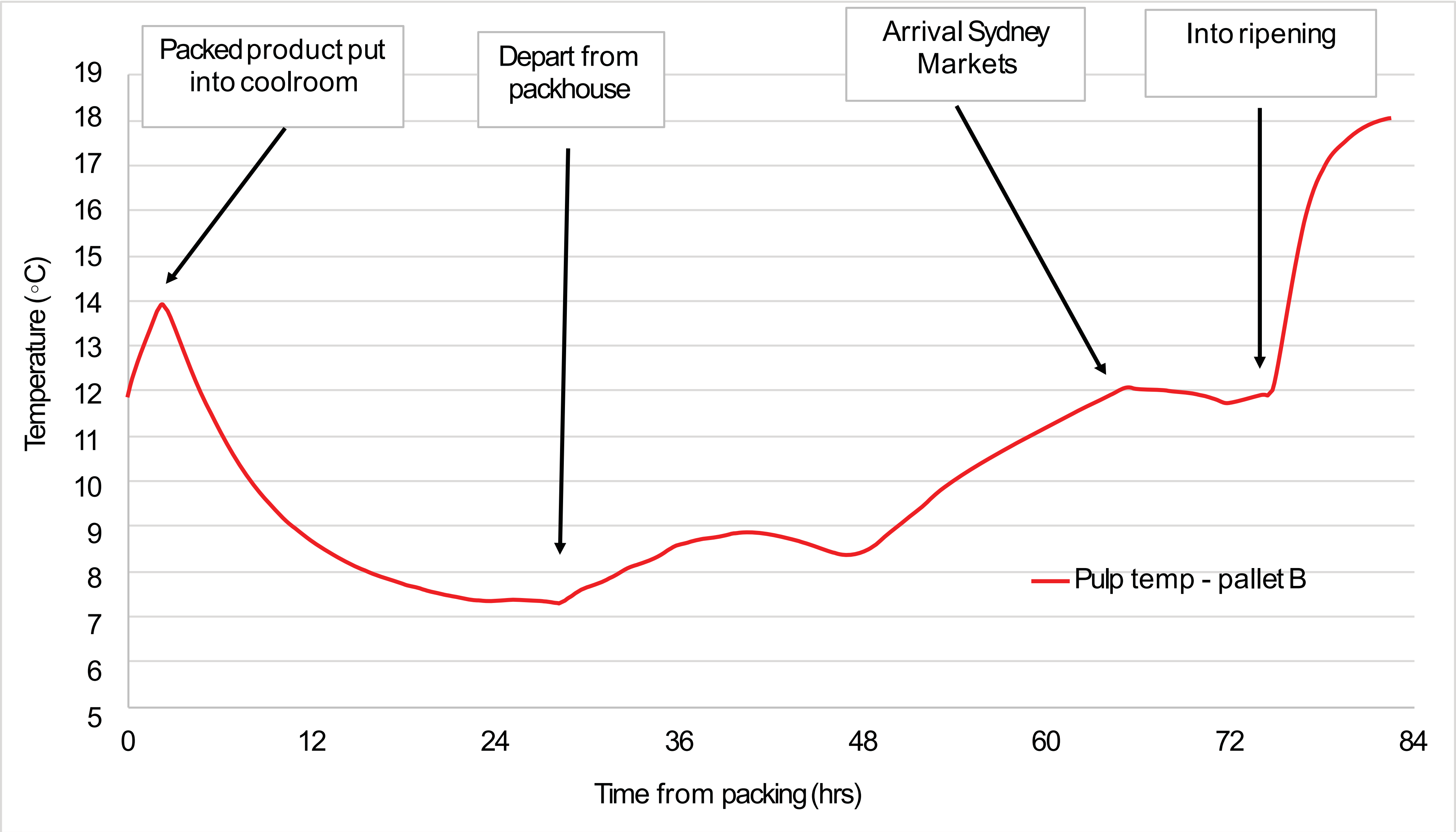
Key supply chain issues

- ***Variability in ripeness***
  - **Temperature management** after harvest
  - **Dry matter** variability
  - **Ripener skills** – are CO_2 and ethylene monitored? Is temperature managed?
- ***Rots, bruises and other internal issues***
  - **Handling** from harvest to retail – avoiding ALL drops
  - **Pre-harvest fungicide** management eg applications during flowering
  - **Postharvest fungicides** – effectiveness if delayed?
  - **Cooling times and temperatures** from harvest through transport and storage
  - **Fruit age**

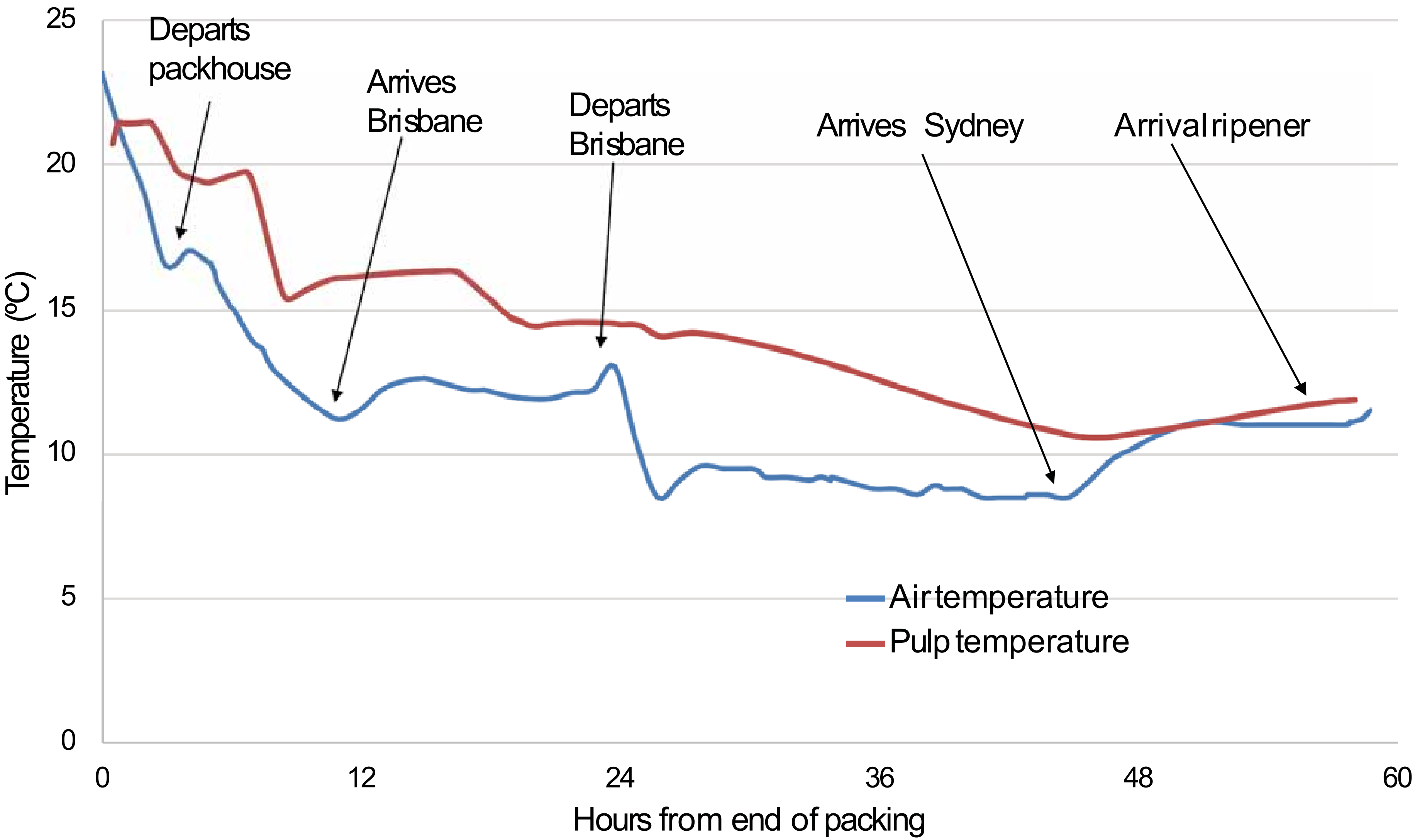
Cool chain studies: Central Qld

- Logging temperatures from harvest to retail
- Comparing quality at:
  - End of pack line
  - Dispatch from ripener
  - Retrieval from retail store

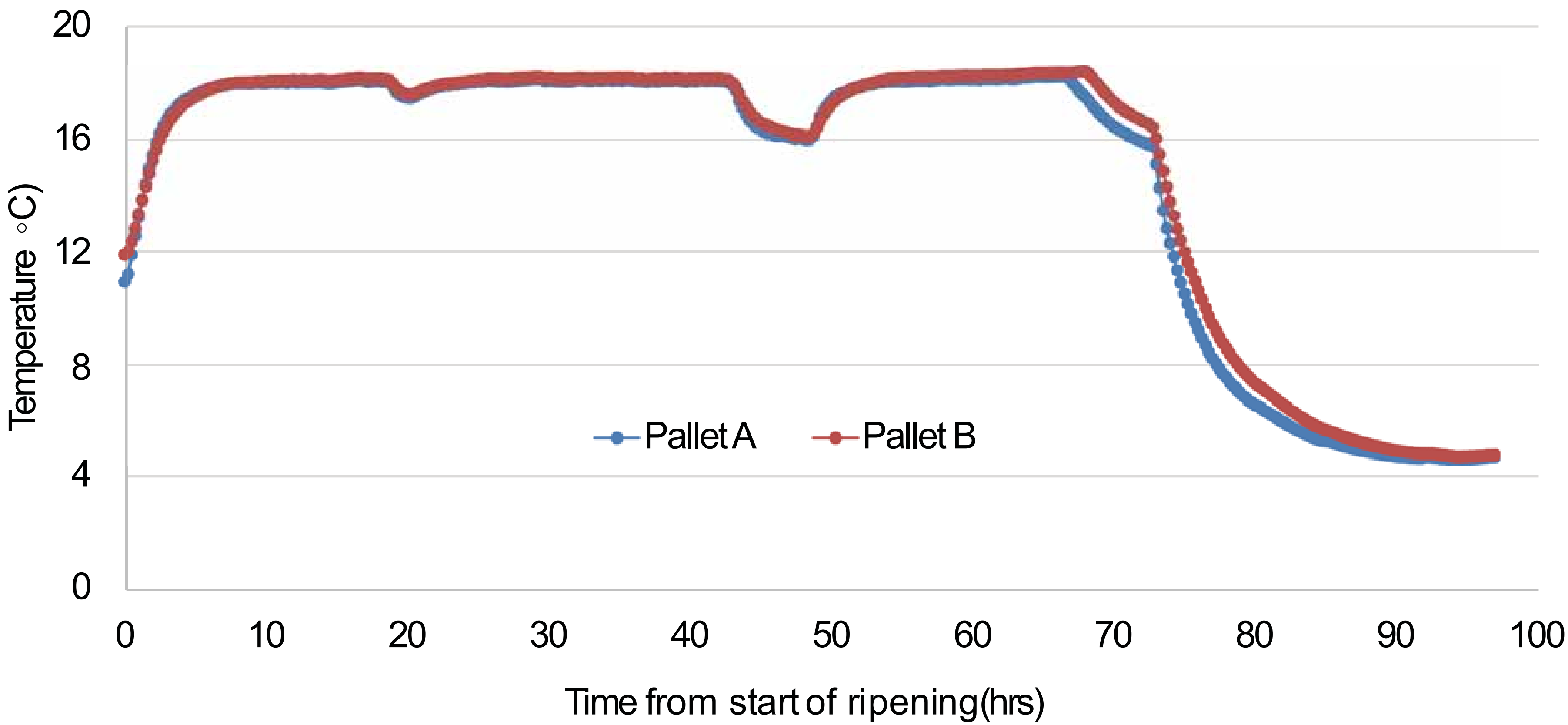
Packhouse A to ripener



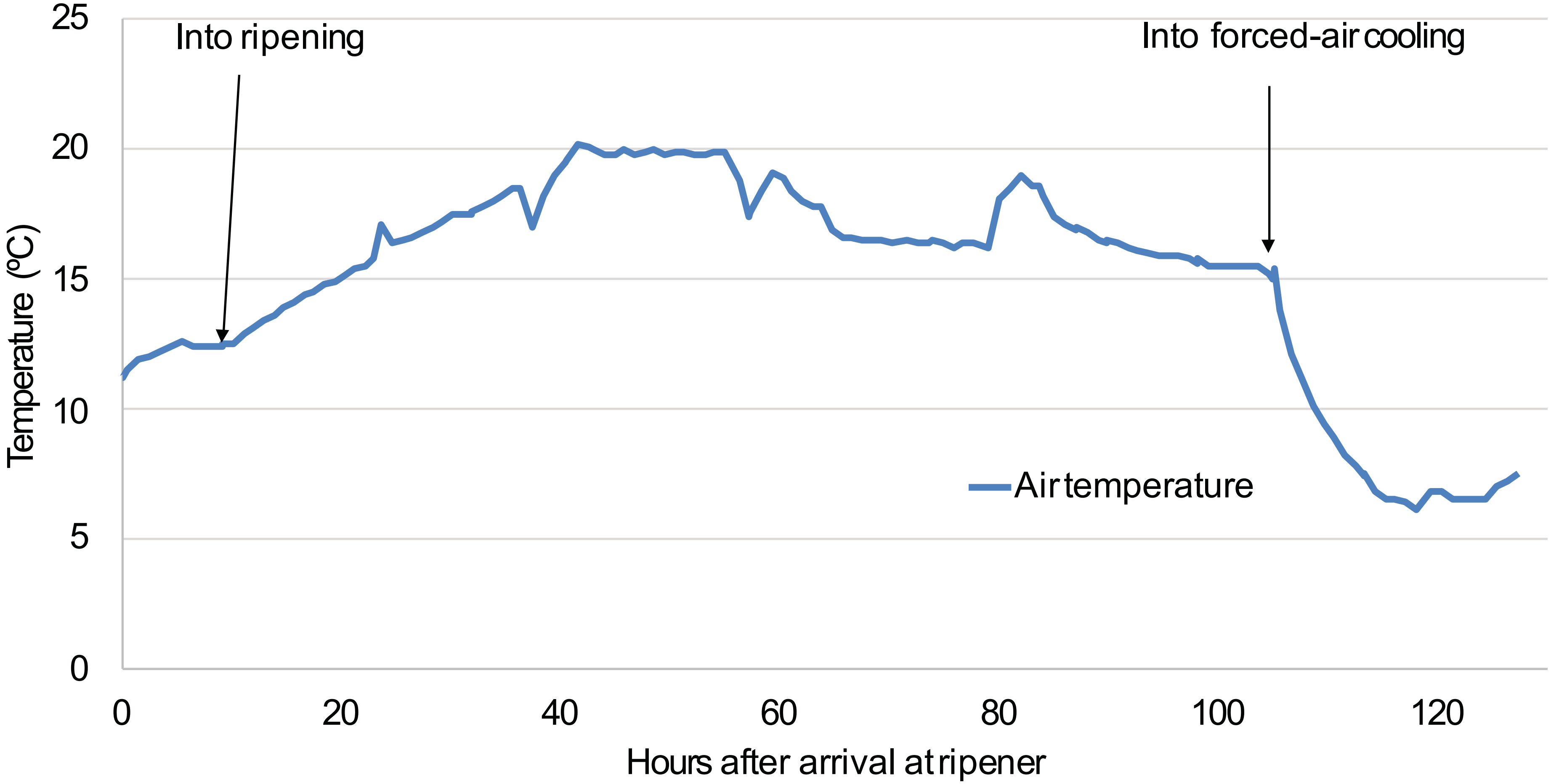
Packhouse B to ripener



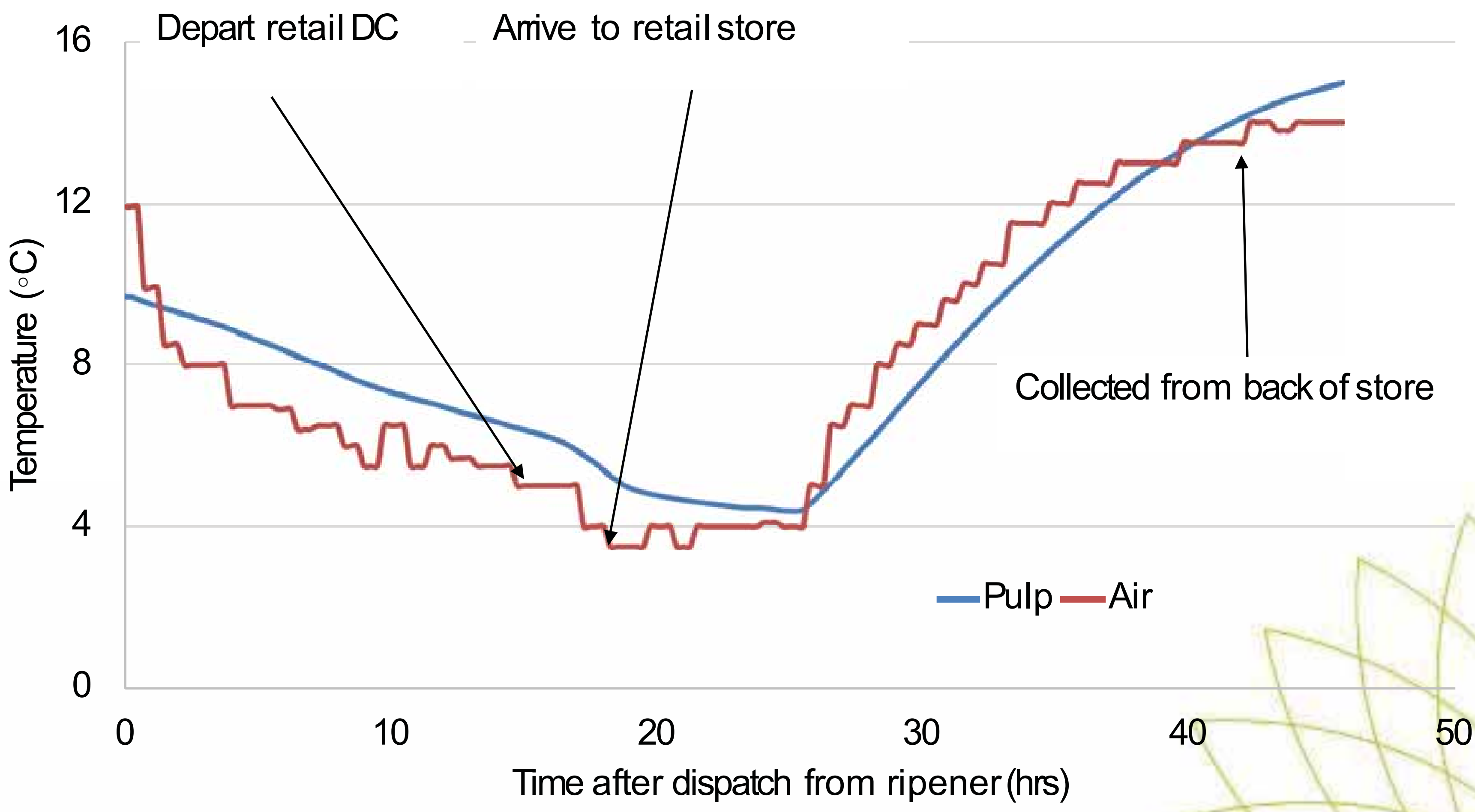
Packhouse A: Ripening



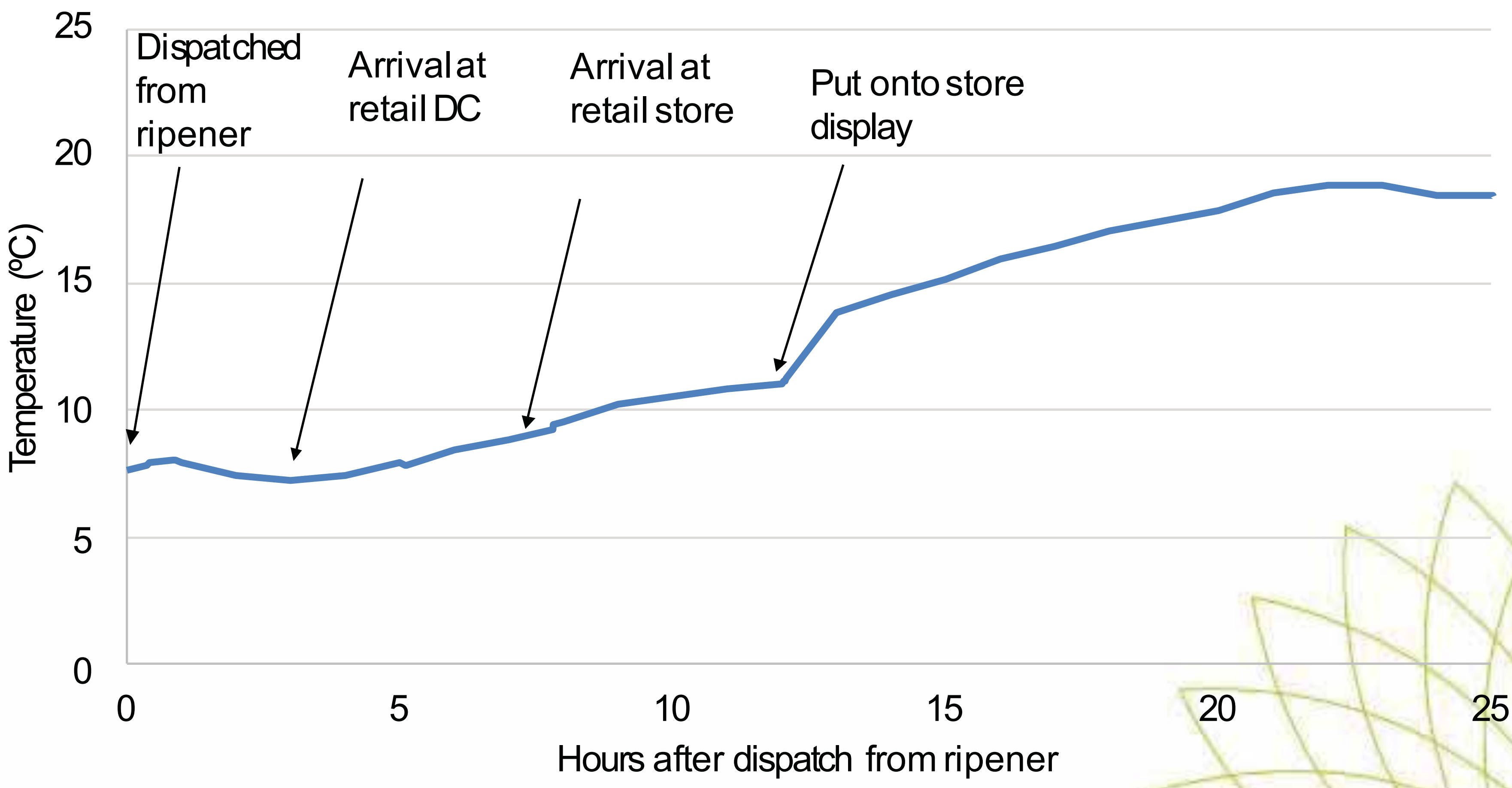
Packhouse **B**: Ripening



Packhouse A: Ripener to retail



Packhouse B: Ripener to retail



Quality assessments

	Number of fruit with internal flesh damage at soft-ripe (n=20)	
Supply chain stage	Packhouse **A**	Packhouse **B**
1. Taken direct from packhouse, stored 5 days, ripened	1	1
2. At dispatch from ripener in Sydney	1	5
3. Retail store	0	6

1. Postharvest quality best practice guide

Harvest

Key points
- Only harvest fruit once it reaches minimum dry matter content
- Harvest dry fruit
- Avoid dropping or bouncing fruit
- Cover fruit in bins to keep cool and reduce sunburn

Prepare for harvest

- Check the operation of harvesting, grading and packing equipment and of cool rooms before the start of harvest, and fix/adjust as needed.
- Clean bins and check suspension on bin trailers / runners.

When to harvest

Fruit need to reach minimum maturity levels to ripen properly and eat well. Dry matter is an excellent indicator of fruit maturity. Test dry matter before picking;

Sample at least **20 fruit per block** from a **minimum of five trees**.

- Select equal numbers of fruit from each side of the canopy (eg east,west).
- Note that fruit at the top of the canopy and large fruit on the northern and eastern sides of the tree are likely to mature first.
- However, size and appearance are not generally reliable indicators of maturity.

Do not start harvesting until fruit meets minimum dry matter content;
- Hass >23%
- Shepard >21%
- Reed, Fuerte >20%

Dates from previous seasons can be a useful indicator when to start testing for maturity. However, maturation can vary from year to year, across blocks within the orchard, and between different cultivars and rootstocks.

Develop a harvest schedule based on maturity zones or blocks and provide clear instructions to pickers and supervisors.

Fruit picking

Hass can be **plucked**, other varieties must be **clipped**.

Hass is recommended to be clipped if;
- Humidity is high / weather is wet
- Fruit is not in the 23-29% dry matter range
- Trees have been stressed
- Growth regulators (e.g. Sunny®) have been used.

Fruit should be picked dry (*if possible*);
- Delay harvest for 48 hours after heavy rain (>20mm in 12 hours)
- Delay harvest for 24 hours after drizzle.

Wet fruit *is more sensitive to mechanical damage/abrasion, and to skin spotting (or lenticel damage), which will increase the risk of rots. If conditions are wet, apply postharvest fungicide ASAP (within <24 hours of harvest)*

Pick exposed fruit first, especially if daily temperatures exceed 30°C.

Careful handling and unloading will reduce fruit physical damage (e.g. skin spotting, bruising, flesh cracking) and the associated risks of diseases.

- **Minimise all fruit drops.**
- Train pickers and monitor them regularly to ensure they are handling fruit carefully.
- Use baffles in picking bags, raise cherry picker slowly.
- Minimise distance between bins and pickers.
- Check equipment for sharp edges or damage.

Bin handling

- Don't overfill field bins.
- Keep bins shaded as much as possible.
- Transfer bins from the field as quickly as possible once full, preferably within 30 minutes. Ensure drivers travel at maximum 20kph and access roads are kept in good condition to reduce fruit bouncing in bins.
- Keep bins in a shaded area on arrival at the packhouse to reduce heating and sunburn.

2. Avocado quality problem solver guide

Covers internal and external fruit defects, and ripening and storage issues

Grey/brown flesh (or diffuse discolouration)

What is it?

- Dark areas in the flesh usually grey to grey/ brown in colour and with poorly defined margins.
- Usually starts at the bottom and near the seed and spreads upwards and outwards.
- May be associated with vascular browning.

What possibly causes it?

- Storing or transporting fruit for too long at standard storage temperatures (e.g. greater than about 3–4 weeks at 5°C) before ripening.
- Holding fruit after ripening at too low a temperature (e.g. below 5-7°C) and/or for too long (e.g. more than 3 days for firm ripe fruit).

How can it be minimised or prevented?

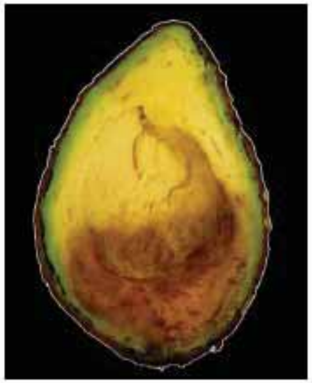
- Ensure effective temperature management measures after harvest as described in the fruit rots section.

Before ripening

- Do not store early-mid season fruit before ripening for longer than 14 days or less depending on fruit age and handling temperatures (see details on Table 2 in the 'Avocado Fruit Quality Best Practices Guide').
- Do not store late season fruit for longer than 5 days.
- Ensure ethylene level during storage is not too high, as it may trigger ripening and cause early onset of symptoms.
- Check fruit condition and length of time in storage daily; remove fruit if there is a risk of fruit starting to ripen.

After ripening

- Do not store Hass for longer than 7 days if at 'rubbery' stage, 5 days if 'softening', or 3 days if 'firm ripe'; do not store green skins for longer than 5 days if 'rubbery' or 3 days if 'softening' or 'firm ripe'.
- Check internal quality of ripened fruit held in storage daily and remove at first sign of flesh discolouration.



3. Checklists

Harvest

Harvest fruit when mature
•Hass >23% dry matter
•Shepard >21% dry matter

Sample at least 20 fruit for dry matter testing from >4 trees/block and opposite sides of the canopy

Pluck – Hass, **Clip** – other varieties

Pick fruit when dry if possible
If Hass fruit are harvested wet then clip stems instead of snapping, apply fungicide ASAP.

Pick exposed fruit first if daily temperatures are >30°C

Minimise fruit drops
Train pickers to empty bags carefully

Manage bins
•Keep filled bins shaded
•Don't overfill
•Transfer to packhouse ASAP BUT max. speed 20kph

Receival

Aim to pack within 24 hours of harvest.

- If fruit pulp is <20°C, keep shaded and pack within 48 hours of receival
- If fruit pulp is 20–30°C *either* pack within 24 hours *OR* room cool to below 15°C and pack within 3 days of receival
- If fruit pulp is >30°C forced air cool below 15°C and pack within 3 days of receival

Keep fruit shaded

Apply fungicide within 24 hours of harvest *especially if fruit have been picked wet*

Control fruit during bin tipping

Thank you

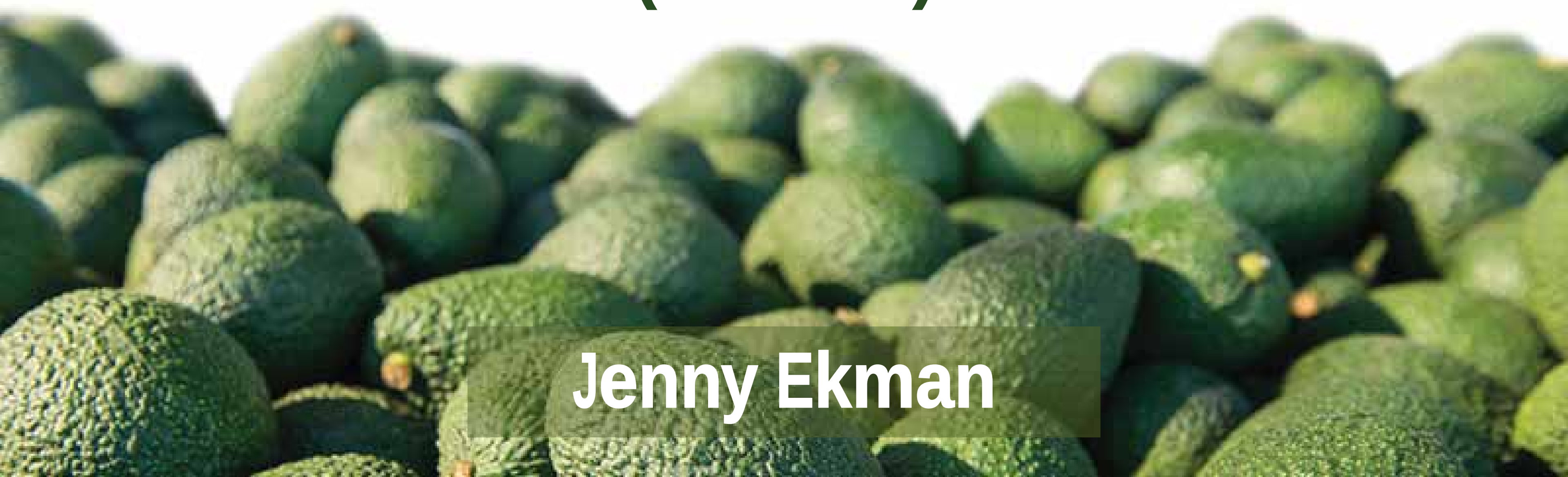
Hort Innovation
Strategic levy investment

AVOCADO FUND

This project has been funded by Hort Innovation using the avocado research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

New Best Practice Resources

(AV15010)



Jenny Ekman

Our project

- Up to **25%** of avocados can have a defect at retail
  - Bruising
  - Rots
  - Vascular browning
  - Internal discolouration

- Poor handling by retail staff and squeezing by consumers contribute to bruising
- BUT internal issues, rots and discolouration are also major issues.. and relate to the whole supply chain…

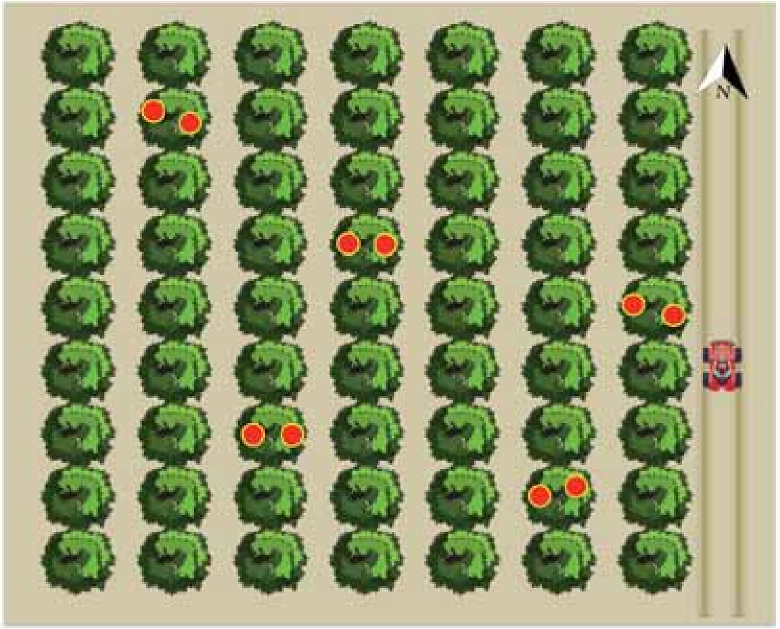
Our project

- Avocado supply chain quality improvement (AV15010)
  - Reviewed postharvest research
  - Packhouse studies to identify and understand issues
  - Refresh existing resources

How harvest practices can reduce quality

Fruit maturity

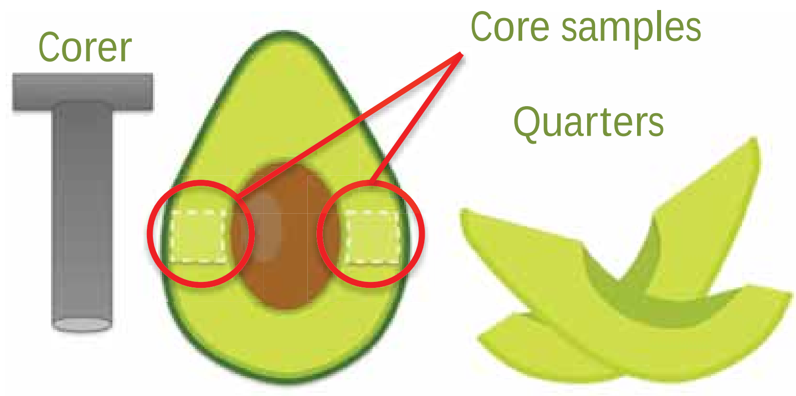
- Fruit should not be harvested until it meets minimum dry matter
  - Hass **>23%**
  - Shepard, Reed, Fuerte **>21%**



Sample at least
- **10** fruit/block from
- **5** randomly selected trees
- Midway up *and*
- On opposite sides

Determining dry matter

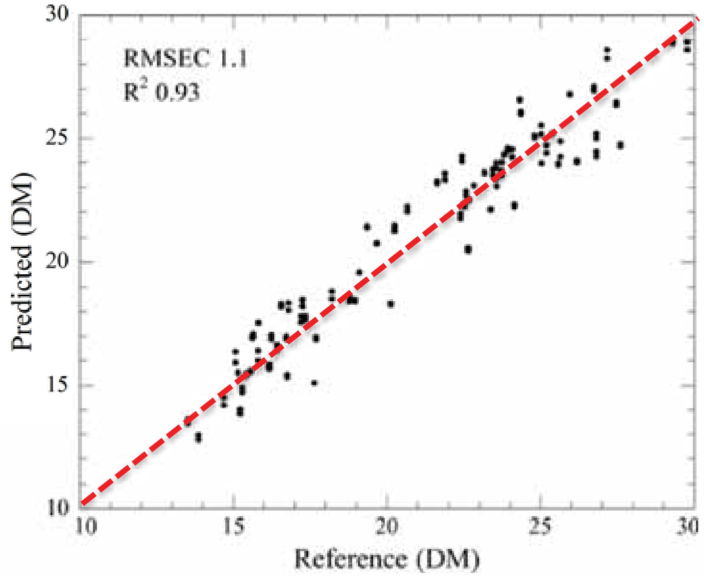
- Careful sampling is ***essential***
- Measure moisture content by;
  - Oven drying
  - Microwave (low power)
  - Dehydrator
  - Moisture determination balance
  - Videos on the Avocados Australia BPR



The more samples you take, the more reliable your estimate of DM will be

Determining dry matter

- NIR for field measurements?

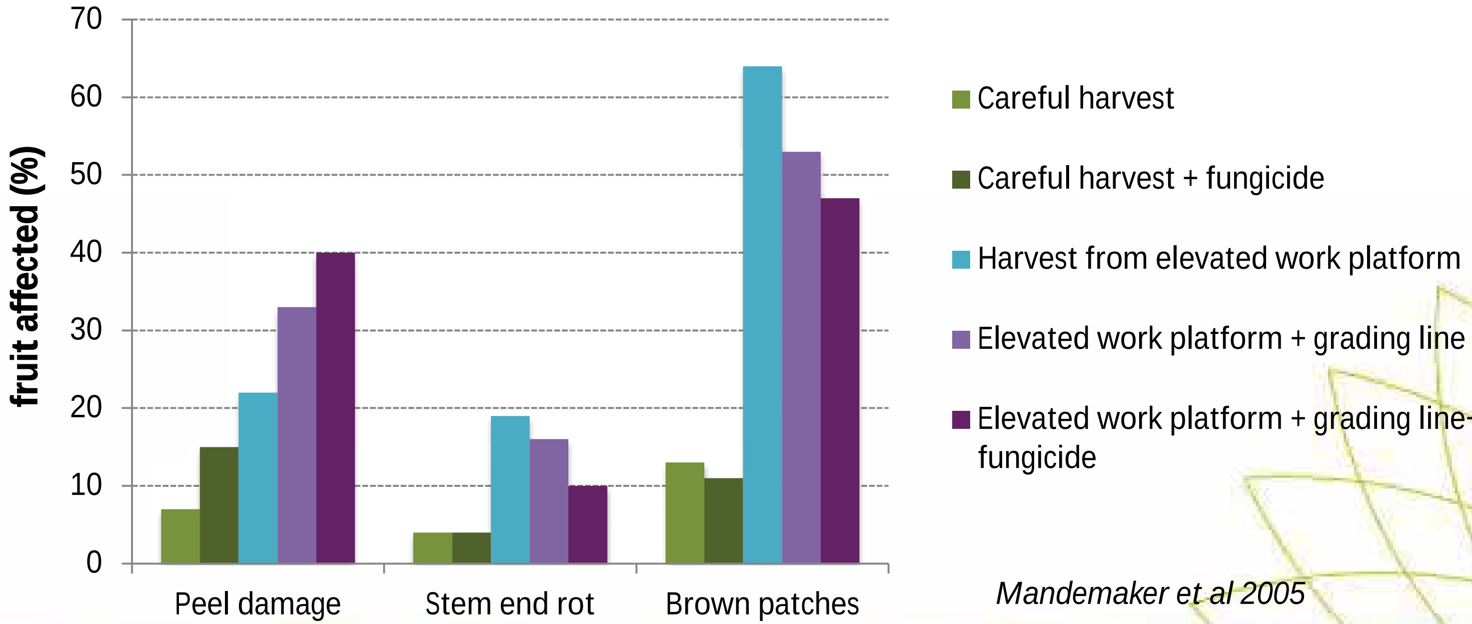


Immature fruit – nearly ready to harvest

Mature fruit – ready to harvest

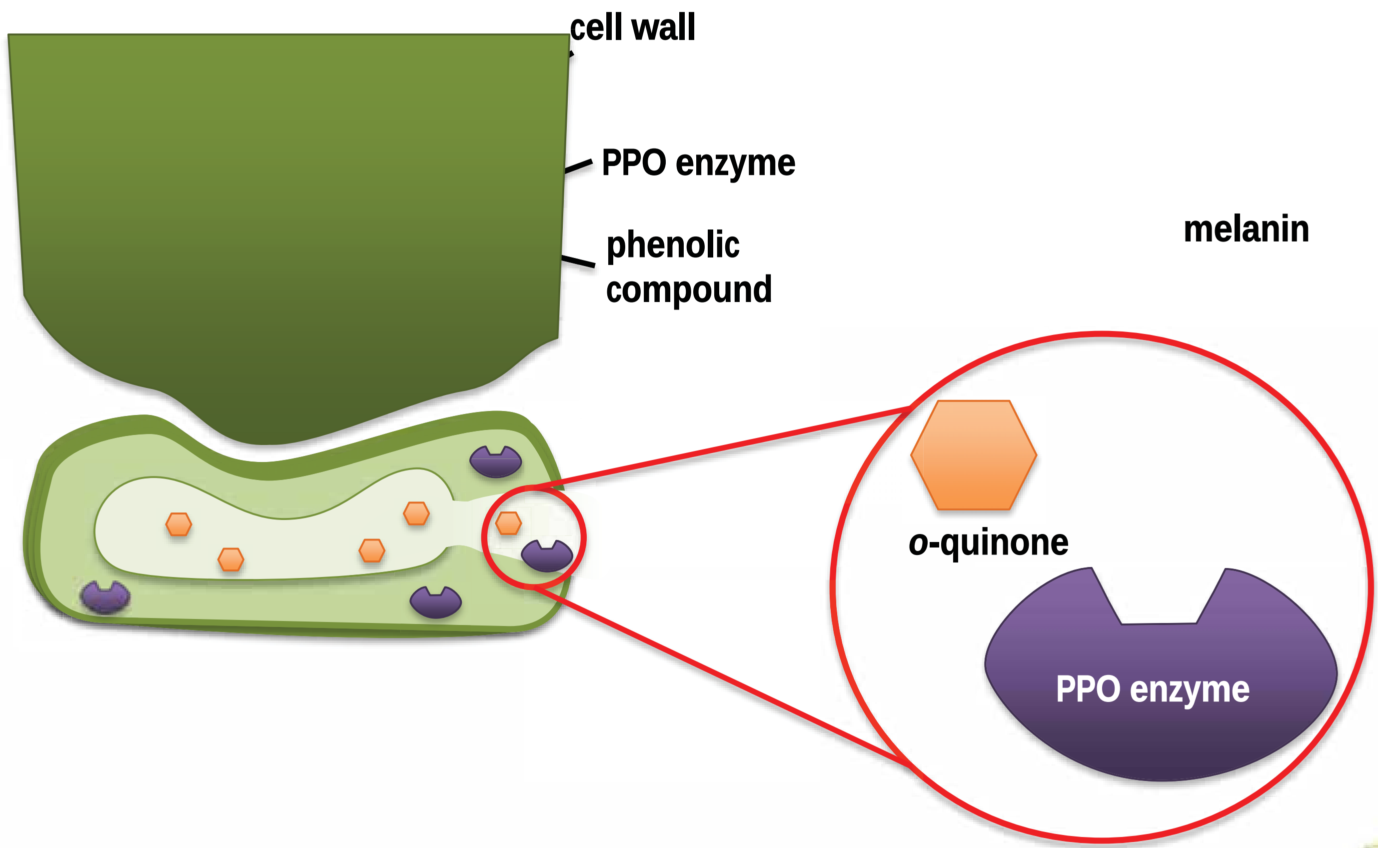
Harvesting

- Previous recommendation was that hard green fruit could be dropped up to 30cm without damage
- More recent research suggests this is **too high...**



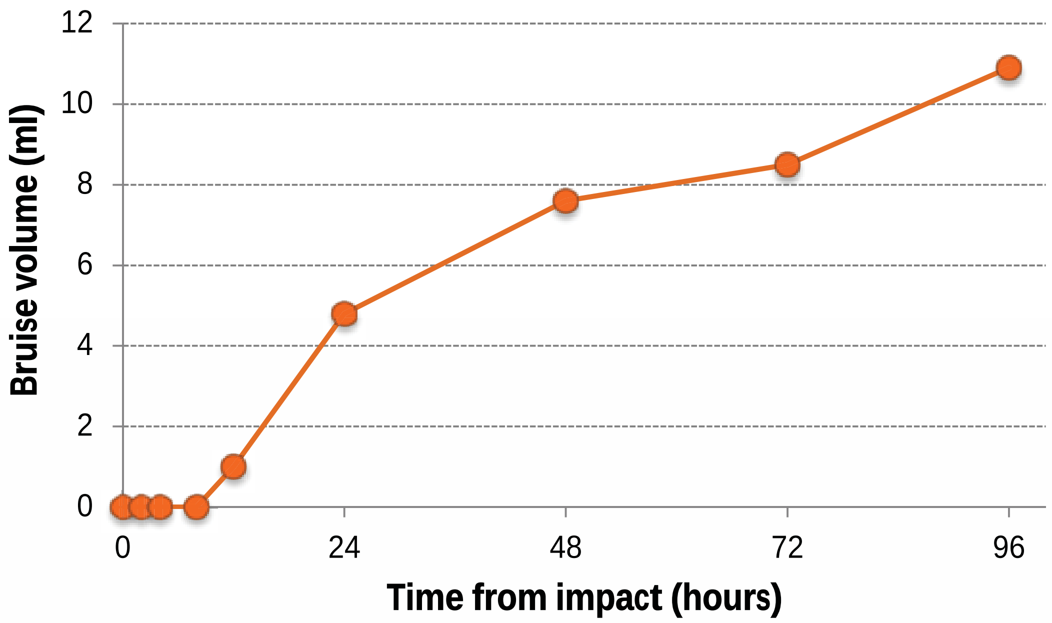
Mandemaker et al 2005

What is a bruise?

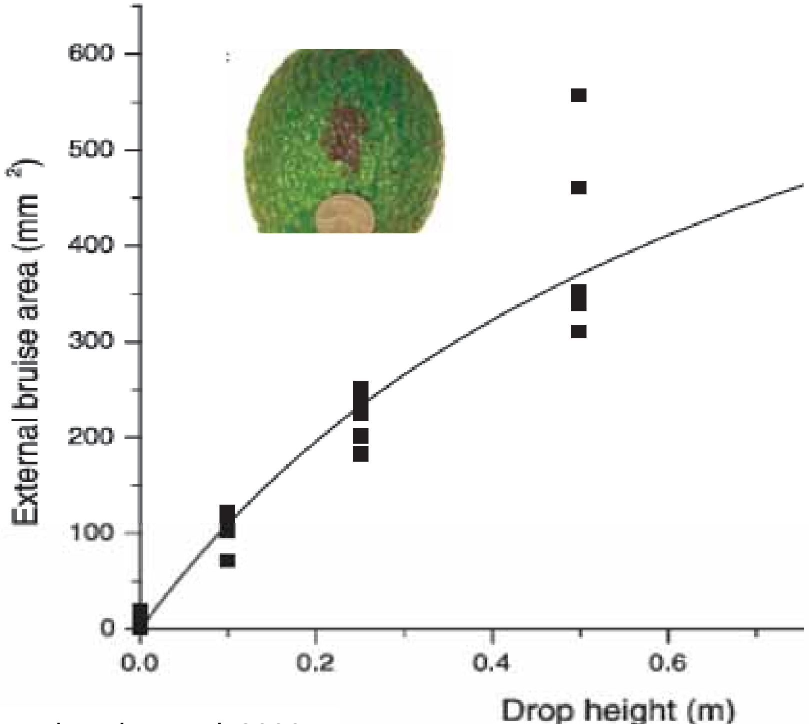


What is a bruise?

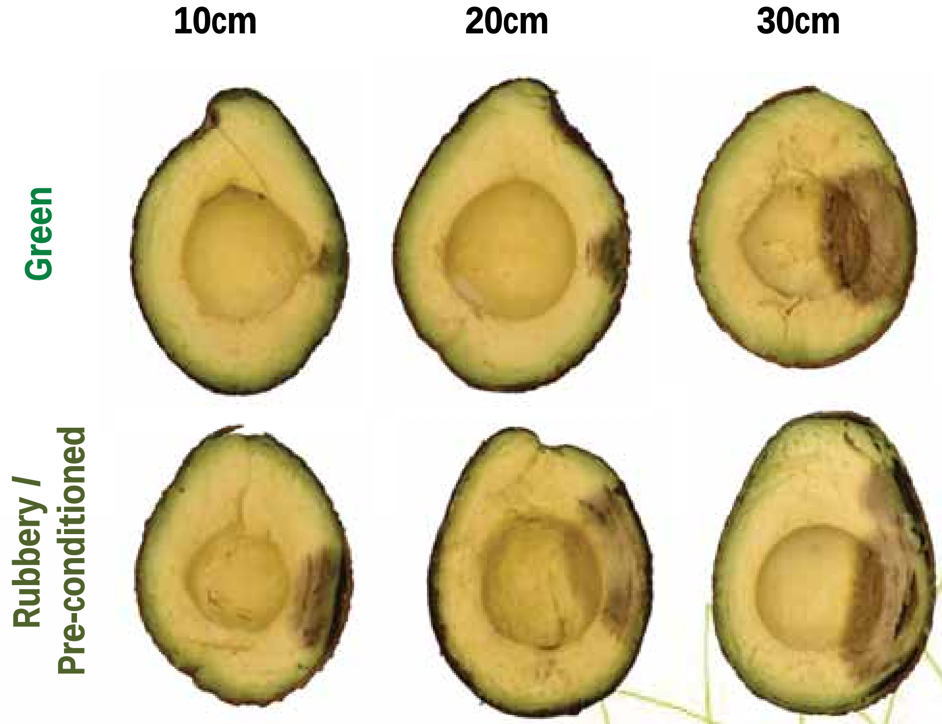
- Reaction is not instant, but occurs over time



Minimise fruit drops



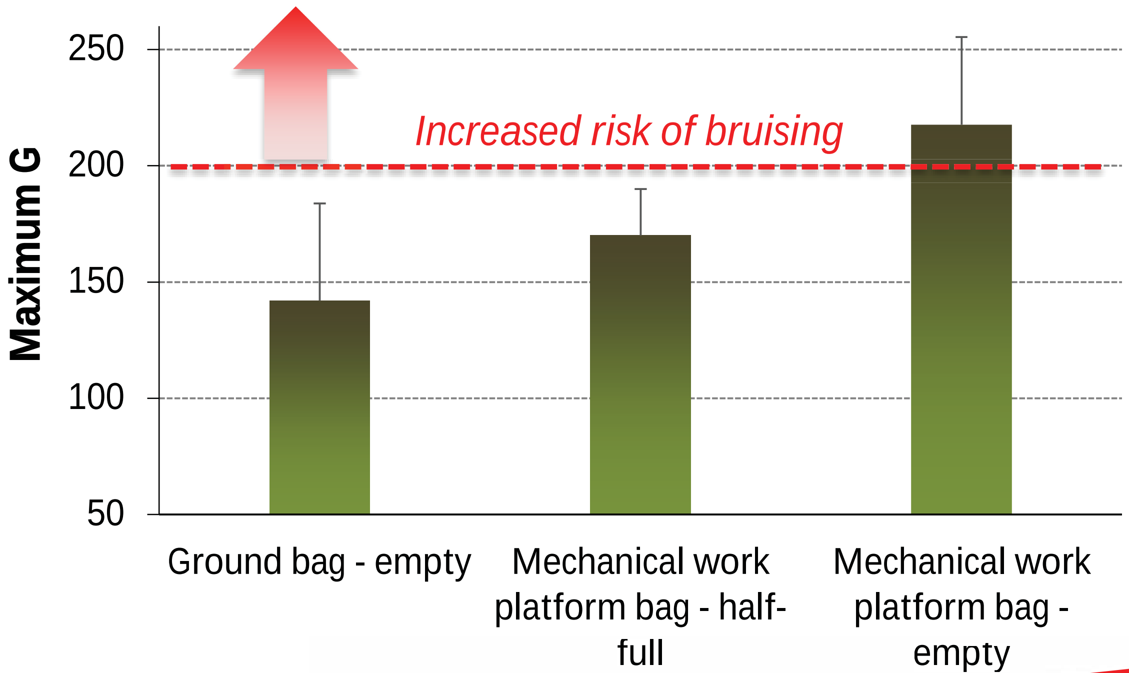
Mandemaker et al, 2006.



Drops (>15cm) can also increase disease, even if no bruising is visible

Fruit drops

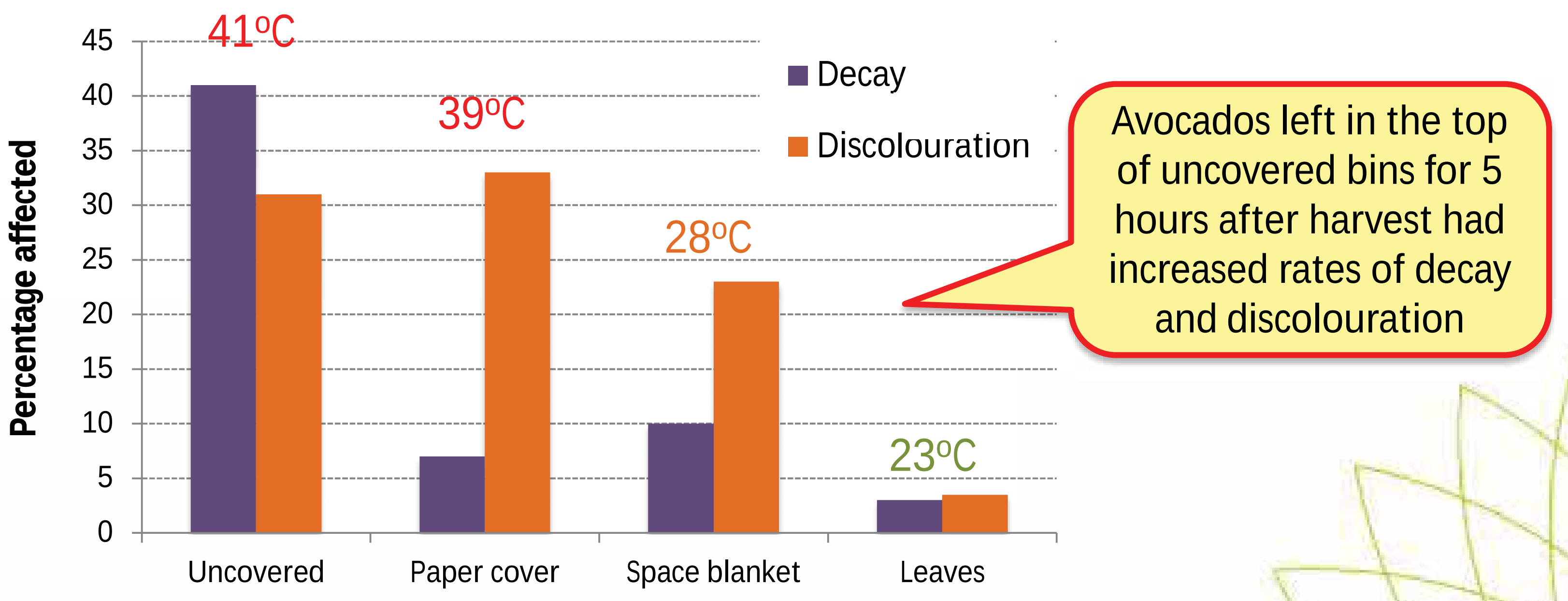
- Significant impacts can occur during picking



ALL fruit drops should be **minimised**

Harvesting

- Fruit can be hotter than the surrounding air
  - Gradients of up to 15°C reported



Arpaia et al, 1992.

Harvesting

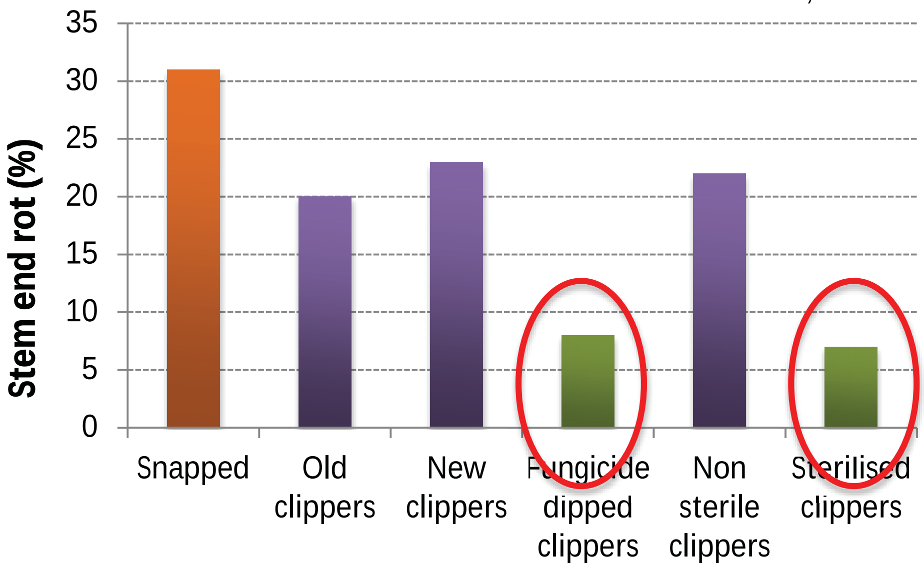
- Avoid harvesting fruit when hot (>30°C)
  - Covering or shading bins is essential
- Avoid harvesting fruit when wet
  - Delay harvest for 48 hours after rain
  - Delay harvest for 24 hours after light drizzle
- If avocados ***ARE*** picked wet then…
  - Clip rather than pluck Hass
  - Apply a postharvest fungicide ASAP

Getting the best from fungicides and sanitisers

Fungicides

- Disease resistance is due to ***anti-fungal dienes***
  - Disappear over time (~25 days)
  - If fruit are warm they disappear quicker!
- Regular application of fungicides ***from early fruit set to harvest*** is critical
- Hygiene and pest management limit disease spread
  - Disinfect cutting tools

Hartill et al, 2002

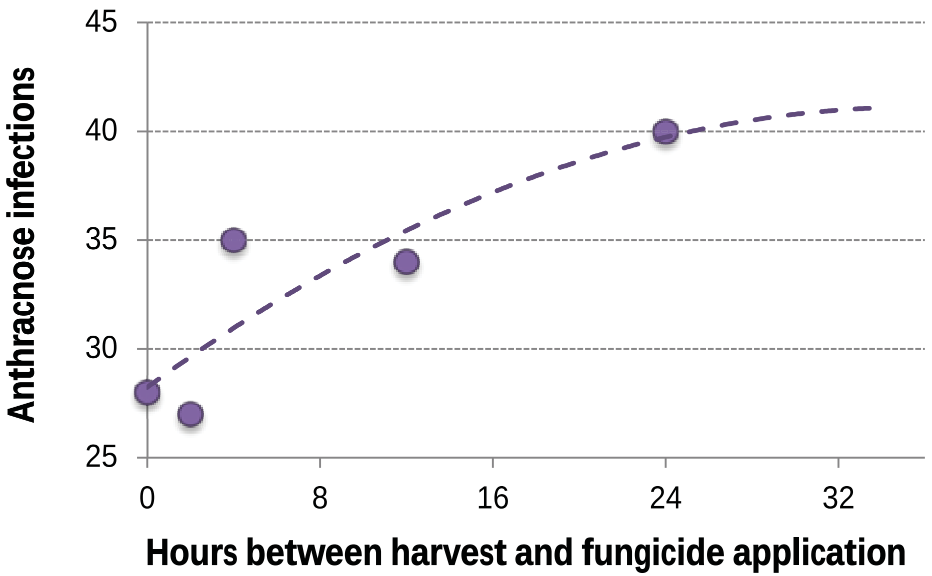


Fungicides

- Fungicide in the field;
  - Start the season with a copper based fungicide
    - ➢ *(Note that red copper oxide sticks better than copper oxychloride or copper hydroxide in rainy weather)*
  - Alternate applications of strobilurins with copper or Thiram®
  - Maximum 3 strobilurin applications / season
- Strobilurins are *partially* mobile in the plant
  - Control disease after infection has occurred

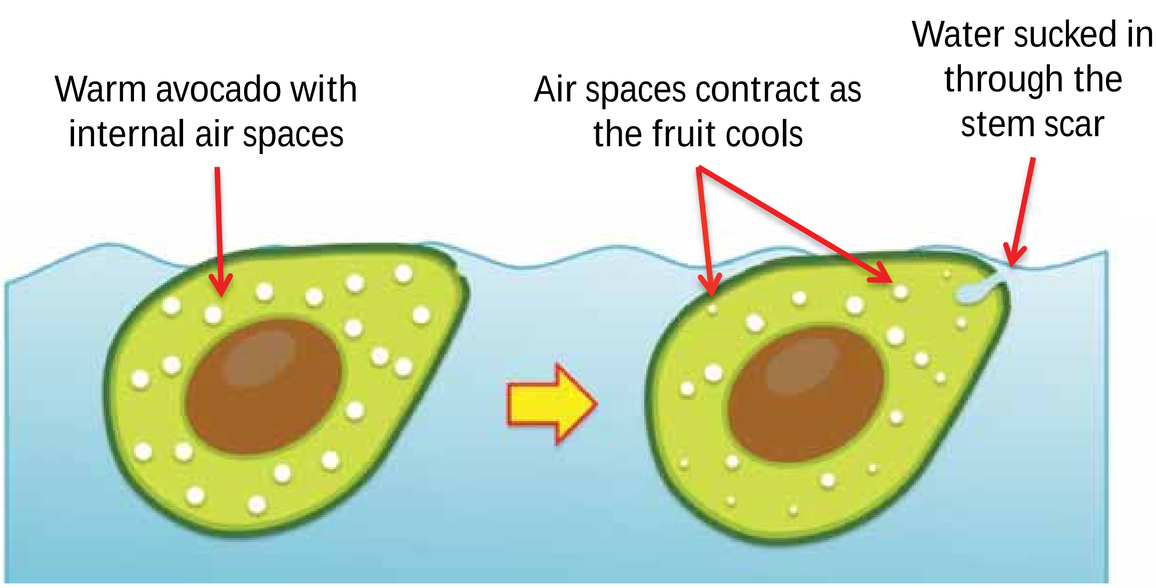
Fungicides

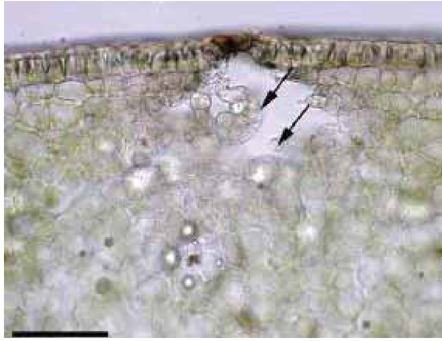
- Fungicide at the shed
  - Postharvest fungicides can reduce disease by **5 – 50%**
    - Response is highly variable…
  - Timing likely to be critical for infections at harvest; Stem end rots
  - Can reduce spore numbers on skin
  - Ineffective against pre-harvest infections



Sanitisers

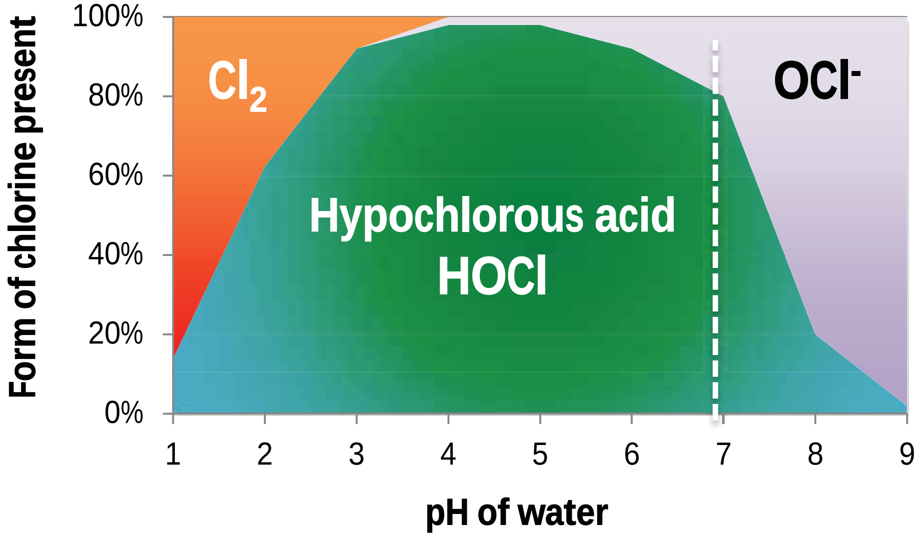
- Water dumps minimise damage during bin tipping and help to clean fruit **BUT** they must contain an effective sanitiser
  - Warm avocados can suck…



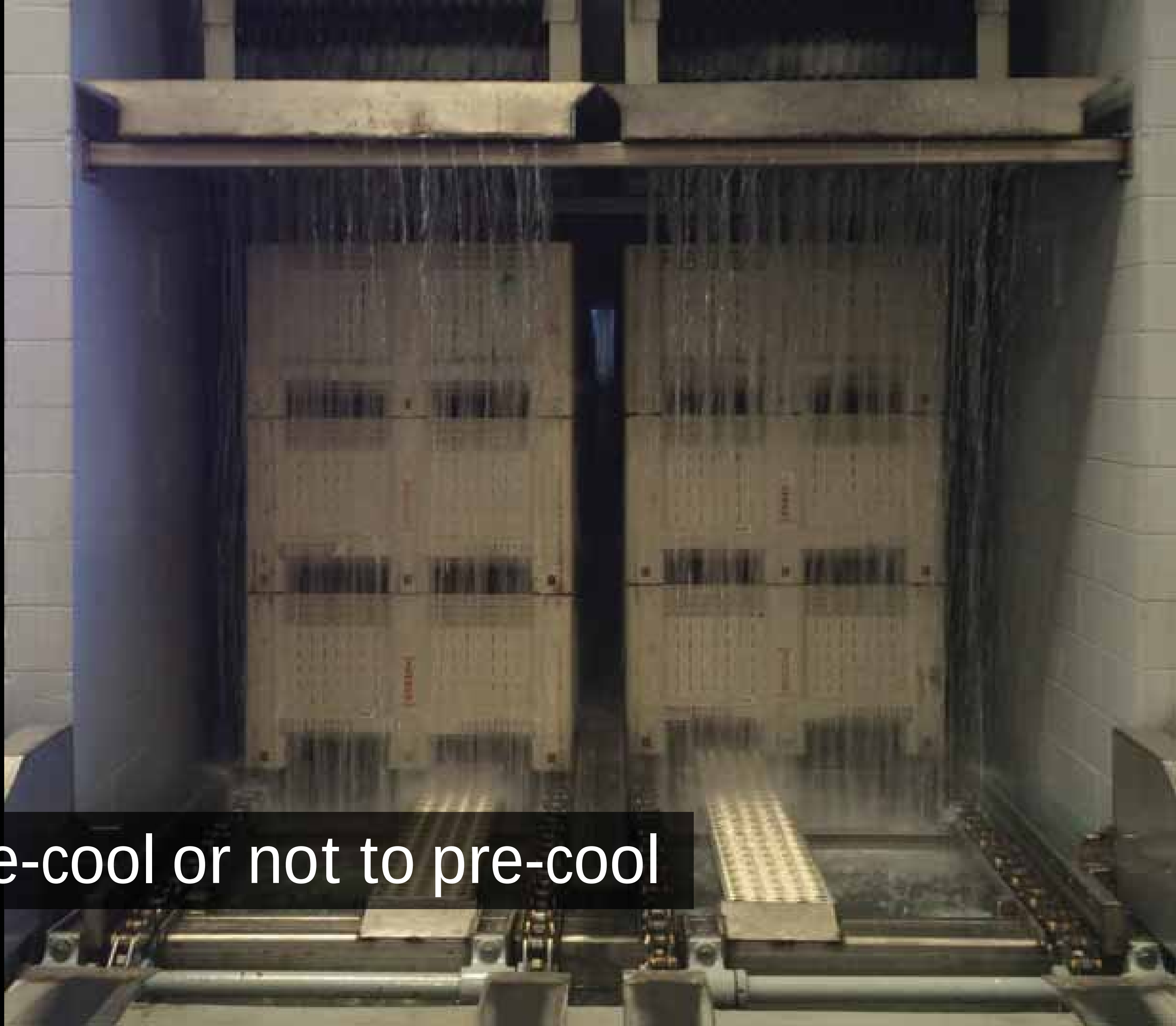


Sanitisers

- Chlorine works great but
  - Best at 50-100ppm
  - Handle with care
  - De-activated quickly if the water is dirty
  - Ineffective at pH>7.5



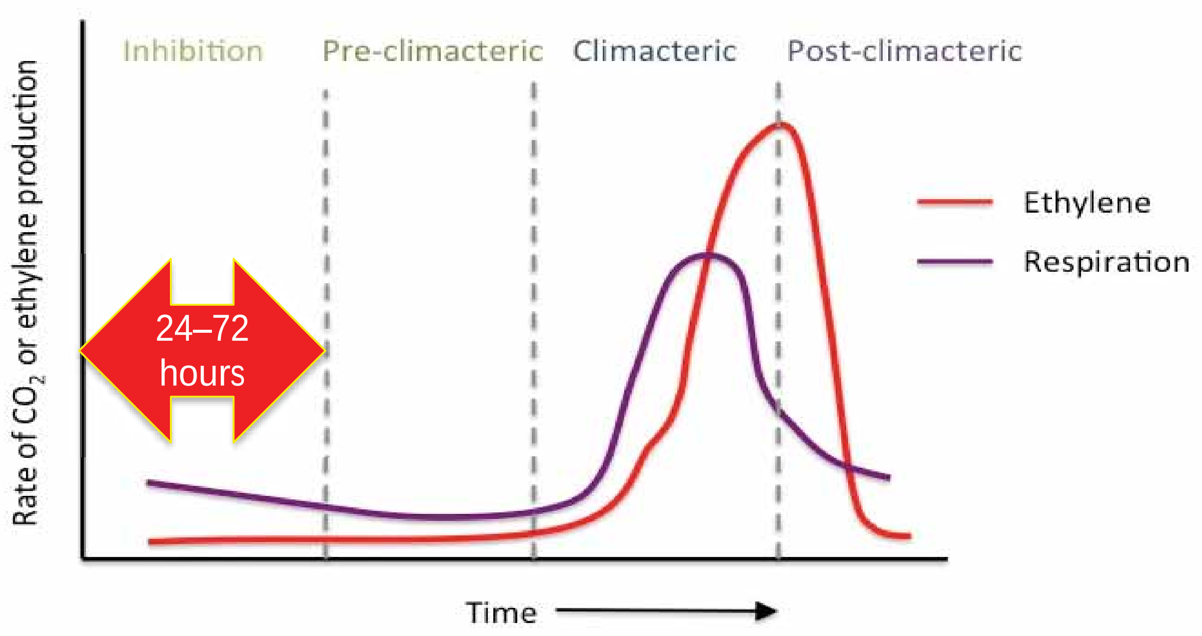
Tsunami® (chlorine dioxide) and Nylate® (bromo-chlorodimethyl hydantoin) are less affected by pH and dirty water than standard chlorine



To pre-cool or not to pre-cool

Pre-cooling

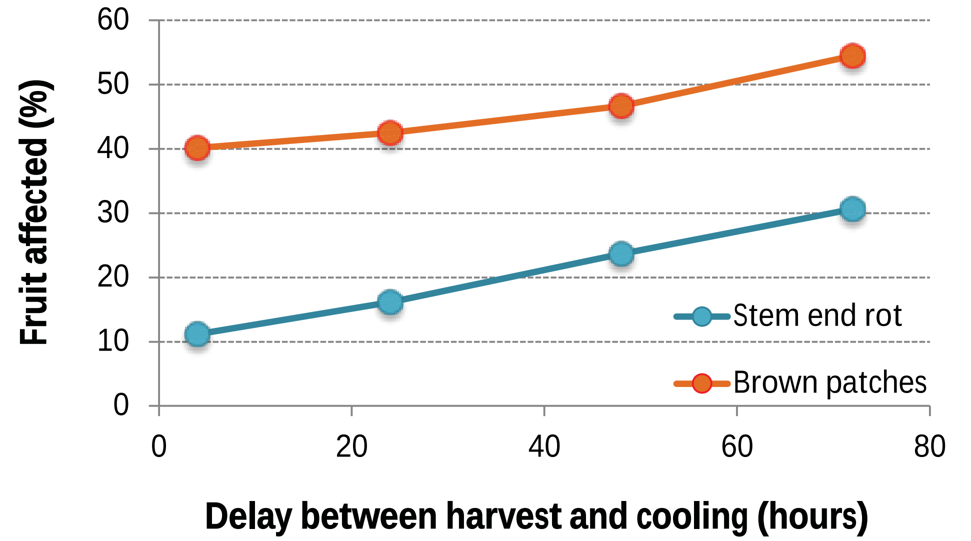
- Avocados don’t ripen on the tree because of the “***tree factor***”
  - Degradation of the **tree factor** depends on temperature + time



- Once ripening starts it is *unstoppable*

Pre-cooling

- The effect of delays are a factor of ***TIME*** + ***TEMPERATURE***
  - Holding fruit at 20°C for 24 hours resulted in higher rates of decay and faster ripening than fruit held at 16°C or 7°C (Yearsley et al, 2002)
  - Holding fruit for 3 days at ~20°C before transfer to 5°C increased stem end rots, with fruit ripening immediately on removal (Lallu et al, 2003)
  - ..



Dixon et al, 2005

Pre-cooling

- Fruit that stay warm after harvest can start to ripen..
- **Always aim to pack and cool within 24 hours of harvest**
  - Particularly if fruit is destined for export *or* may not be marketed for >2 weeks

But what if I **can't** pick, pack and cool within 24 hours?

Immediate actions depend on fruit temperature

Pre-cooling

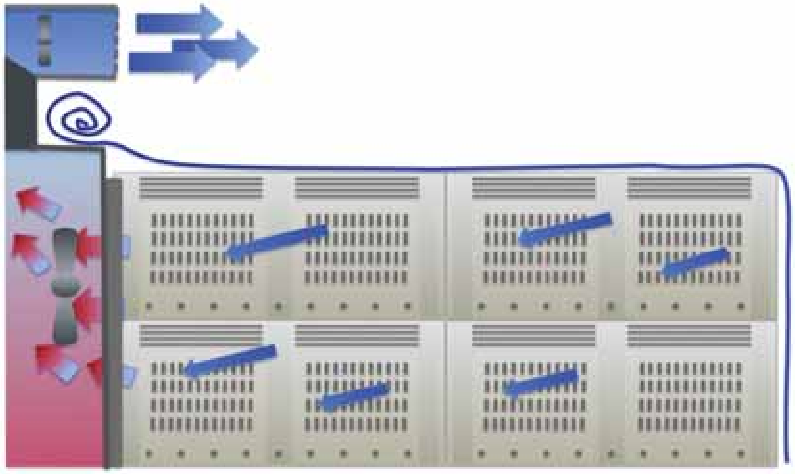
- Check fruit temperature
  - If pulp temperature is **<20^{o}C** THEN
    - keep cool, pack within 48 hours
  - If pulp temperature is **20–30^{o}C** THEN *either*
    - Pack within 24 hours *or*
    - Cool to <16^{o}C, pack within 3 days
  - If pulp temperature is **>30^{o}C** THEN
    - Cool to <16^{o}C within 6 hours using a forced air system
    - Pack within 3 days

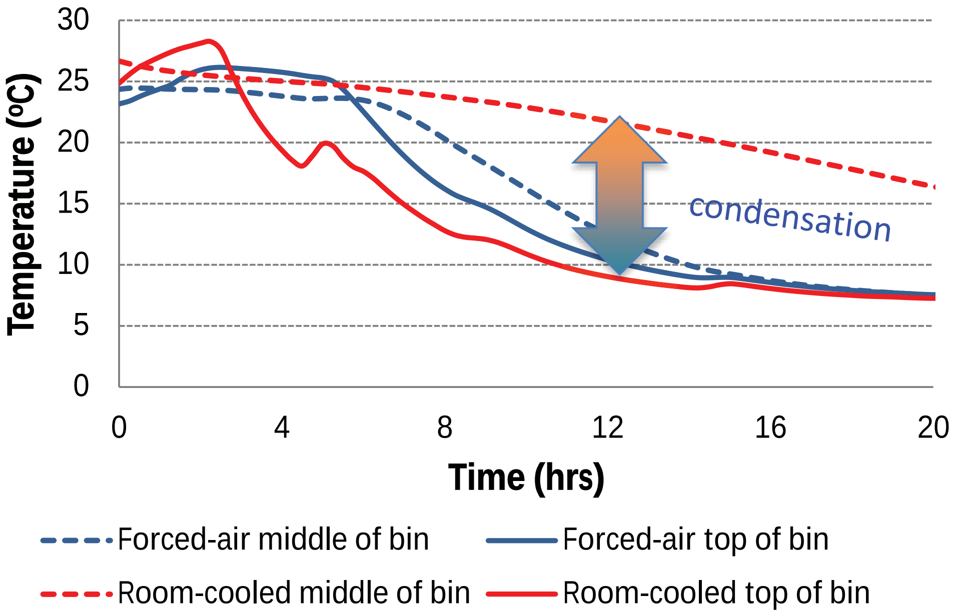
If room cooling…

Don’t overload the room!

Pre-cooling

- *Forced air systems can remove heat up to **10x** faster than room cooling*
  - Avoids condensation
  - More efficient use of coolroom space

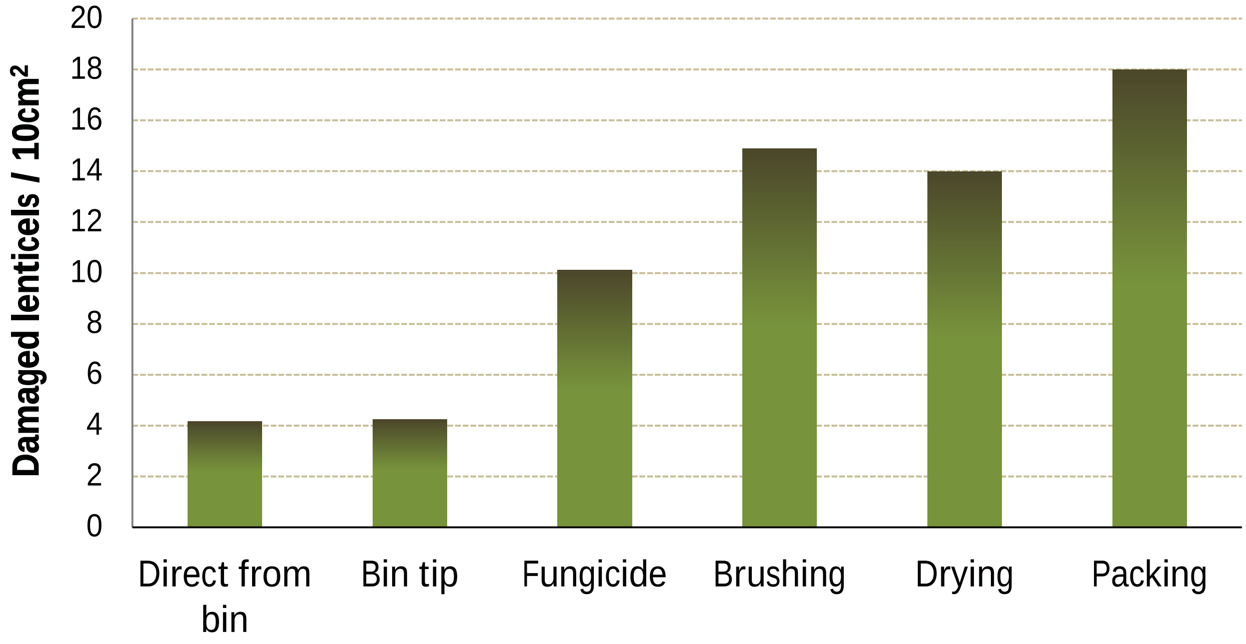




Avoiding damage on packing lines

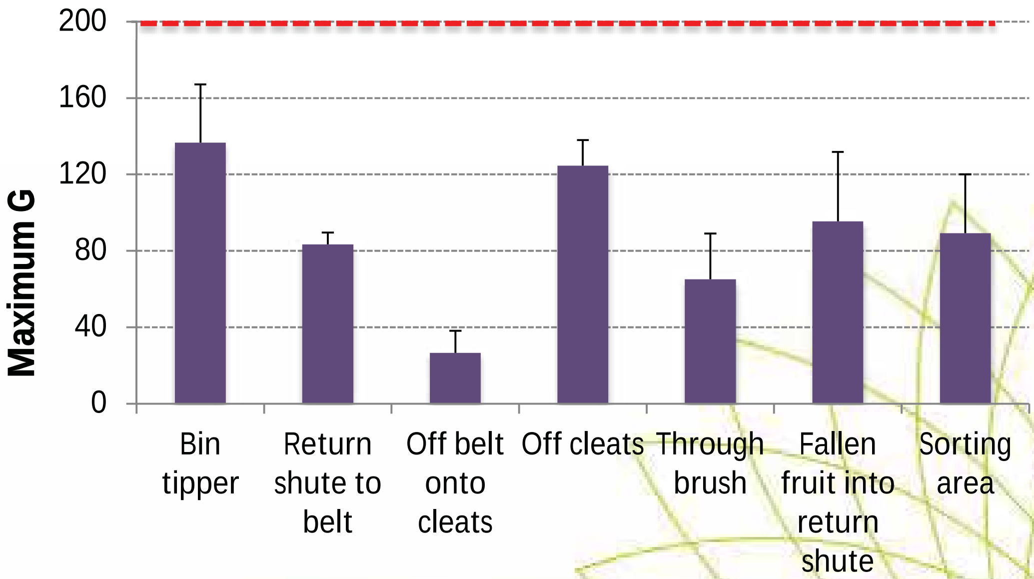
Damage on packing lines

- Fruit may need to be cleaned, but over-brushing can cause skin damage



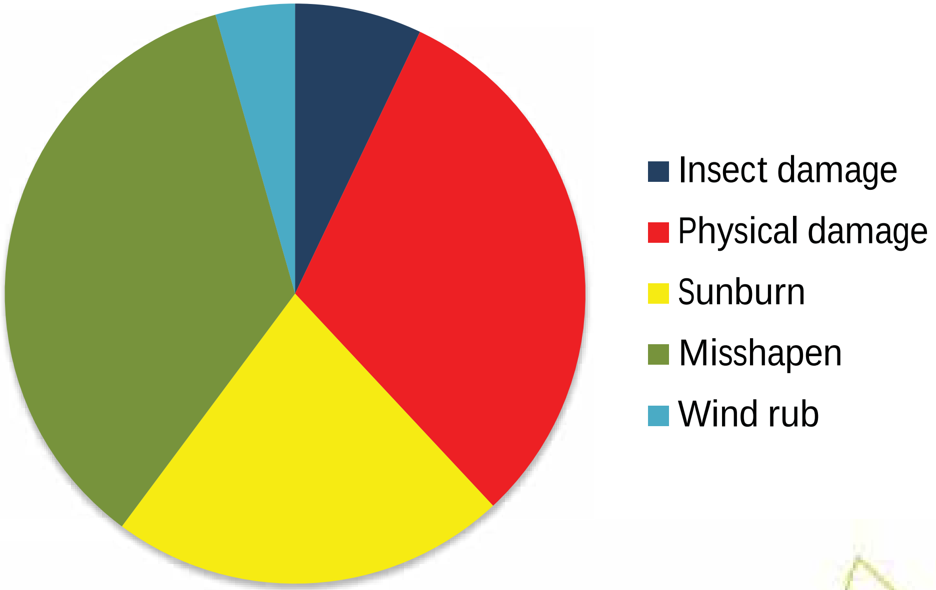
Damage and packing lines

- To reduce damage
  - Keep lines short and flat
  - Use soft brushes
  - Make sure drops/direction changes have baffles and padding
  - Don't run the line too fast
  - Avoid fruit-to-fruit bumping
  - Don't overcrowd fruit
- Measure impacts
  - IRD



Reject bin analysis

A reject bin analysis can help identify ***if*** there are issues and ***where*** they are occurring



Video on the Avocados Australia BPR website


Postharvest cooling

Cooling

The three most important things postharvest are...

- ***Delays in cooling allow fruit to start ripening.***
  - Increased chilling sensitivity
  - Increased rots
  - Variable ripeness at retail
- ***Warm fruit loses moisture.***
- ***Room cooling is very slow***; 0.5^{o}C per hour

Temperature

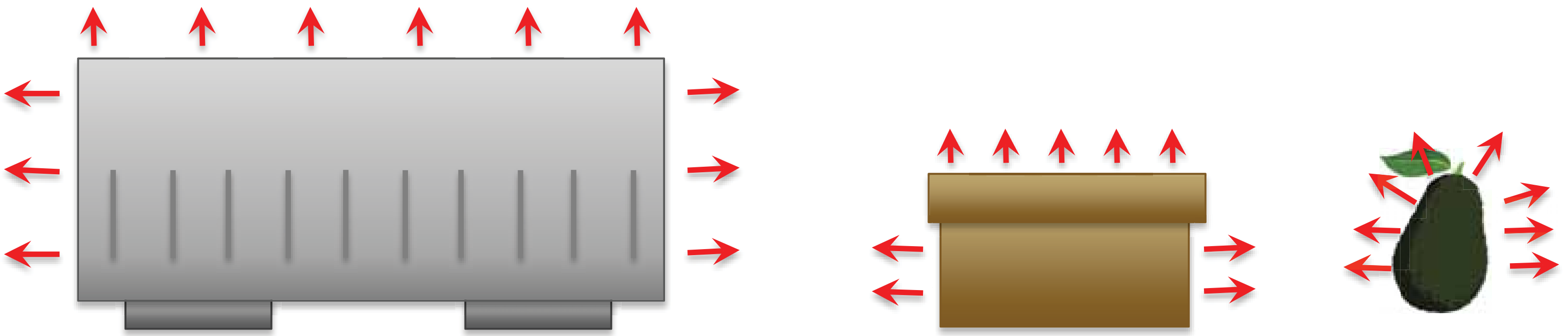
Temperature

and

Temperature

Why room cooling is so slow..

Energy transfer (cooling) from the object (avocado) to the cooling medium (air) is through the contact surface

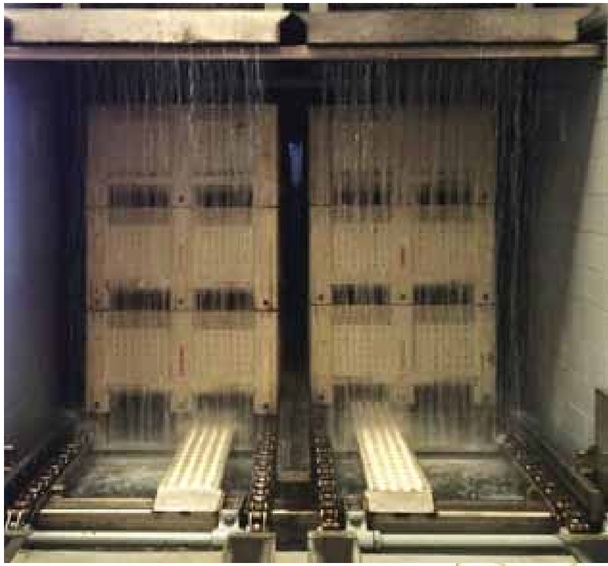


Forced air systems

- Forced air cooling is *FAST* and efficient
  - Vents or cutouts need to line up and cover at least 5% of surface area
- Adjust the air-flow
  - May be diminishing returns at speeds >24 $L/kg^{-1}/min^{-1}$
  - Tarpaulins need to fit **TIGHTLY** to force air through packed trays and cartons

Keeping fruit cold

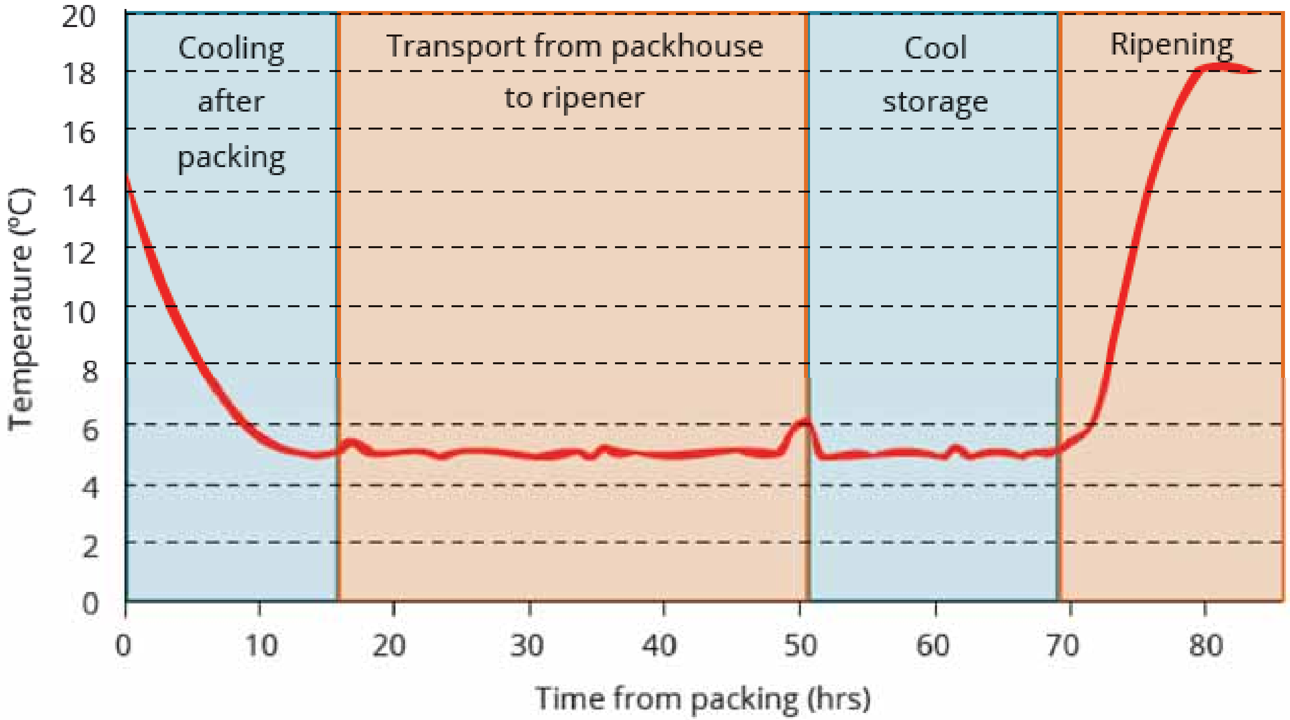
- Monitor pulp temperature
  - Turn fan off once fruit are within 2-3^{o}C of the target
- Hydrocooling is faster than forced air, but
  - Uses more energy
  - Definitely done *before* packing not after!
- Cool fruit thoroughly before transport
  - Hass should be **5^{o}C** and green skin varieties **7^{o}C**




Transport
DARDANIA
Logistics
8
Are you getting the cold you paid for?

In an ideal world...

- Temperatures would be well controlled

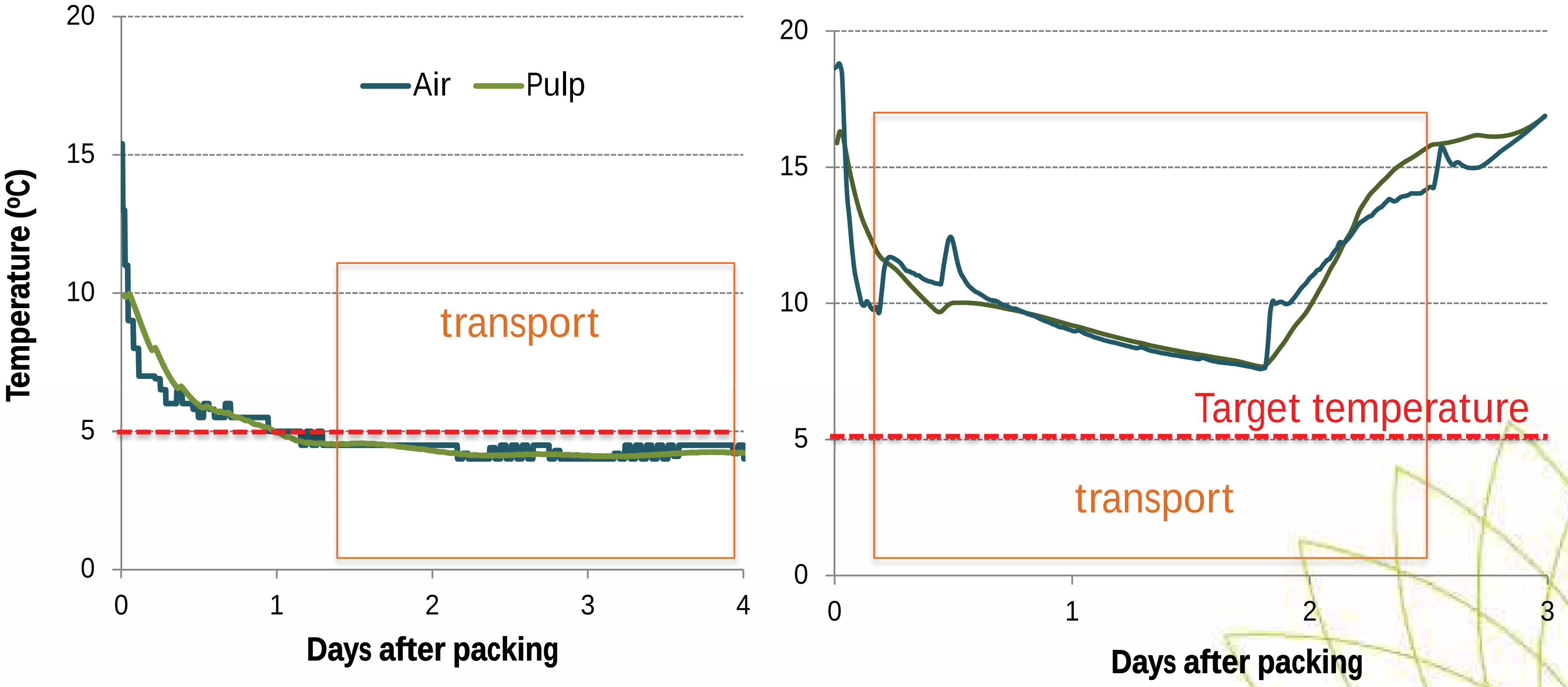


Cool chain studies

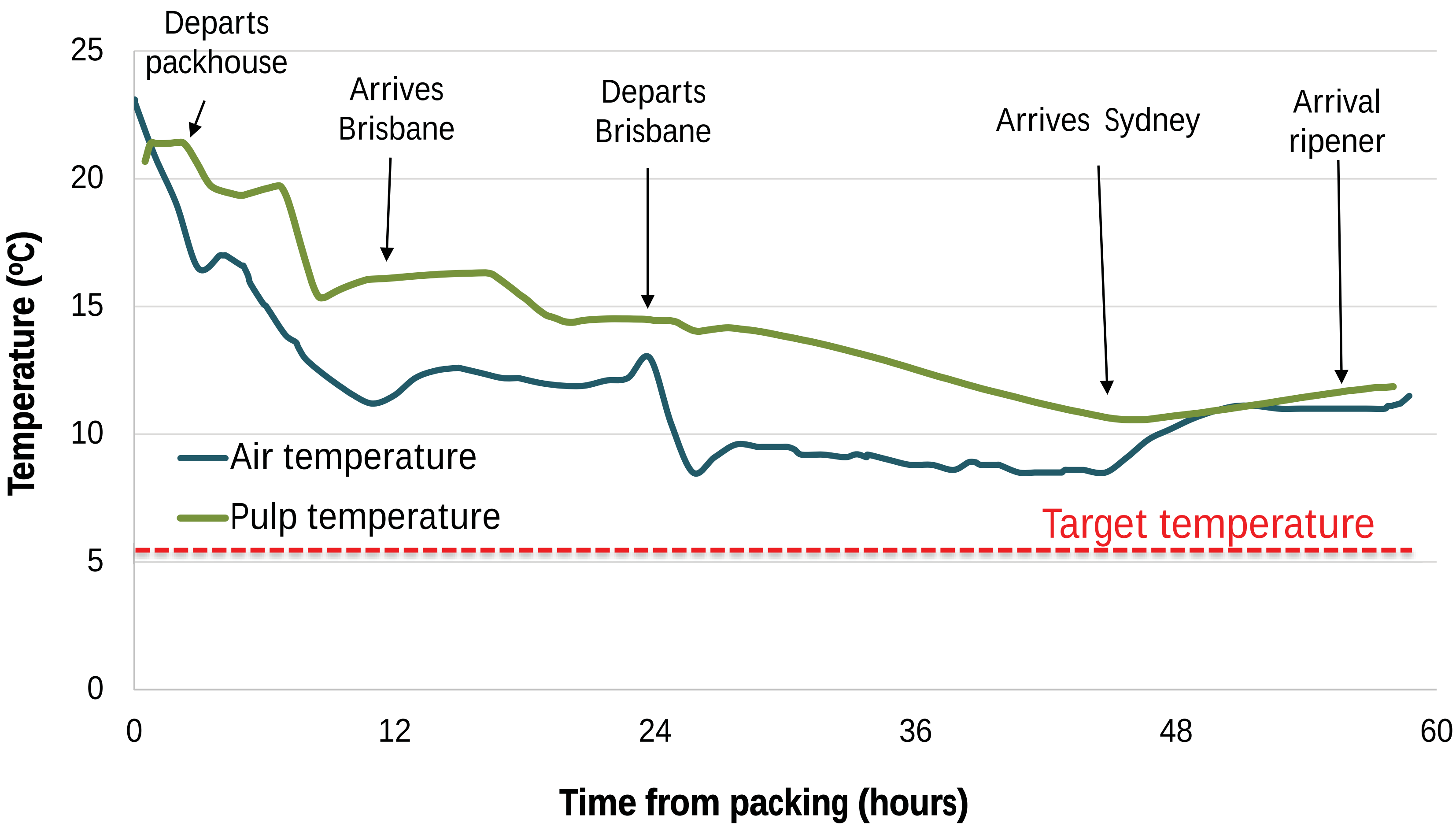
- So how close are we?
  - Logged temperatures from harvest to retail
  - Examined outturn quality

A tale of two supply chains

- Two WA pack-houses sending fruit to the east coast



Poor temperature control is common



Effect on quality

	Packhouse **A**	Packhouse **B**
Fruit with internal damage at packing	5%	1%
Average temperature during transport	**9.2°C**	**14.5°C**
Temperatures during ripening	17–18°C *Average 17.9°C*	12–20°C *Average 16.9°C*
Fruit with internal damage at dispatch from ripener	5%	**25%**
Fruit with internal damage at retail	0%	**30%**


HB
2491
TOYOTA
TOYOTA
What the wholesaler did next...
Ripening

What the ripener needs to know

- ***Dry Matter*** content is critical to ripening time
- ***High temperatures*** increase the rate of ripening but reduce quality
  - Early season fruit at 18-20^{o}C
  - Late season fruit at 16–18^{o}C
- If fruit has started to ripen during transport it **CANNOT** be cold stored but must be ripened immediately
- Stored fruit should be ripened based on fruit age and condition **NOT** when it was delivered

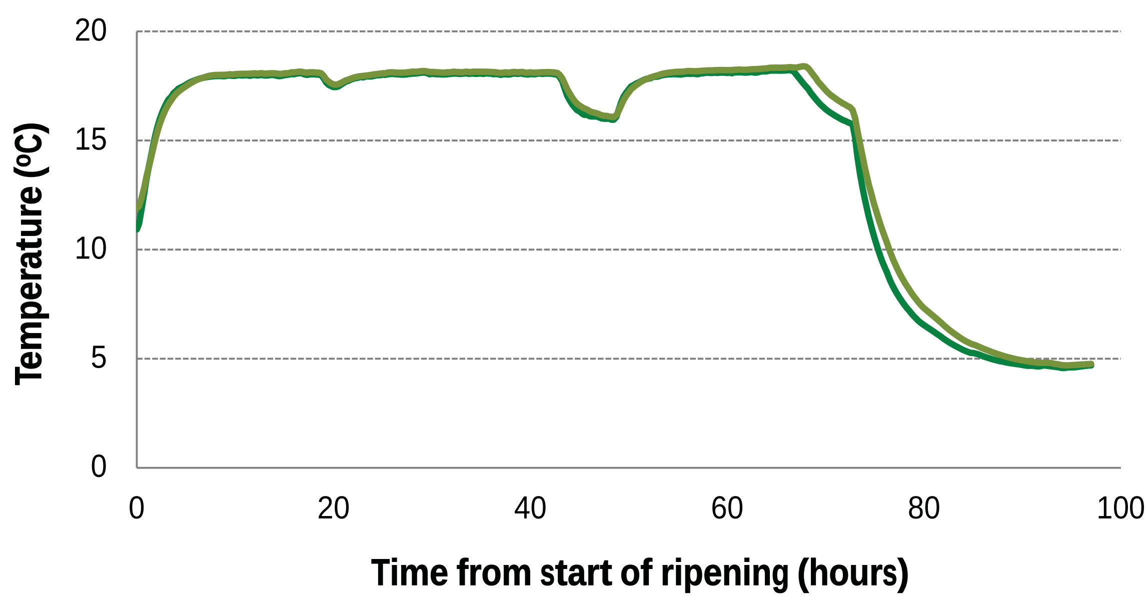
Ripening

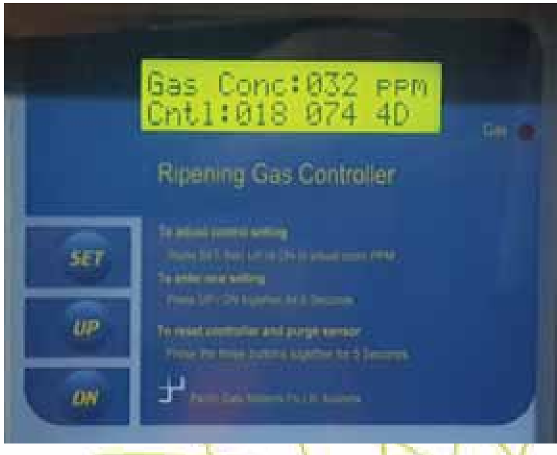
- ***Fruit age is critical***
  - Anti fungal dienes disappear after ~25 days
  - Old / overmature fruit ripen quickly but rots develop
- Avoid storing for more than 2 weeks before ripening
  - Longer storage times increase disease and internal defects
- If temperature management has been sub-optimal, fruit should be ripened sooner

Avocados can commonly be in the supply chain for 3 weeks *and still not ripe*

Ripening

- Choose a ripener who…
  - Has forced air systems to increase, stabilise, and decrease temperature
  - Can monitor ethylene *properly* (inside and outside the ripening room!)





Avocado Stages of Ripeness

	1 HARD	2 PRE-CONDITIONED (Rubbery)	3 BREAKING (Softening)	4 FIRM RIPE	5 RIPE
Description	No give with strong thumb pressure.	Slight give with strong thumb pressure.	Deforms 2–3mm with moderate thumb pressure.	Deforms 2–3mm with slight thumb pressure.	Deforms easily with gentle hand pressure.
Use	*Just Picked* Can be cold stored, easy to transport.	*Ripening* Ready to eat in about three days when held at room temp	*Good For Retail* Ready to eat in two days or less when held at room temp	*Ready to Eat* Good for slicing	*Eat Now* Good for slicing, smashing, spreading
Handling	Susceptible to skin damage when dropped	Susceptible to bruising	Susceptible to bruising	Highly susceptible to bruising from squeezing or dropping	Highly susceptible to bruising by squeezing or dropping
Storage	Ripen at 16-20°C, or store at 5°C (Hass) or 7°C (green skins)	Continue ripening at 16-20°C	Ripen at 16-20°C or hold at 5°C (Hass) or 7°C (green skins)	5°C (Hass) or 7°C (green skins)	5°C (Hass) or 7°C (green skins)
Firmness					
Penetrometer	*>10kgf*	*5-10kgf*	*2-5kgf*	*1-2kgf*	*0.5-1kgf*
Densimeter	*>91*	*90-91*	*86-89*	*74-85*	*65-73*

Note for Hass: Firmness, rather than skin colour is the better indicator of ripeness - depending on maturity, Hass avocados can remain partially green when ripe or already have dark skin colour at Stage 1
Note for green skins: The same stages apply for green skin varieties, however their skin remains green when ripe

Avocados Australia

Hort Innovation


AUSTRALIAN AVOCADO
SUPPLY CHAIN
Best Practice Guide
Hort Innovation
AVOCADO FRUIT QUALITY
Problem Solver
Hort Innovation
AUSTRALIAN AVOCADO
SUPPLY CHAIN
Checklists
Hort Innovation

Hort Innovation
Strategic levy investment

AVOCADO FUND

This project has been funded by Hort Innovation using the avocado research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

ahr applied horticultural research

Avocado supply chain quality improvement (AV15010)

Outline

- Best practice literature review – ***how can we do better***?
  - Format of the review
  - Key findings – what do we know
  - How can this help the Australian industry
  - Gaps in knowledge
- Review of resources – ***how do we get the message across***?
- Next steps
  - What we want from this meeting

Project objectives

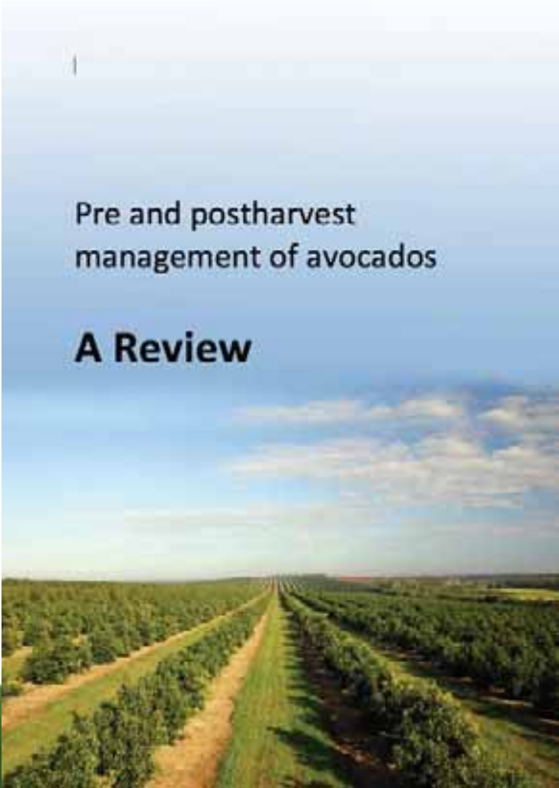
Objectives

1. Increase the adoption of best practice in cool chain management and postharvest handling across all sectors of Australian avocado supply chains from orchard to retail
2. Reduce the incidence of body rots and other quality defects in avocado fruit (25 → 10%)
3. Increase the awareness across the supply chain of factors that predispose fruit to quality defects

Pre- and postharvest review

- Much has been written about pre- and postharvest management of avocados
  - 8,750 papers on CAB
  - 150,000 results on Google Scholar
- Completed a 70 page review
- Both pre- and postharvest factors have a significant effect on postharvest quality

yet there is so much we don't know!



Pre-harvest: Nutrition and fungicides

- Lots of research on pre-harvest effects on postharvest quality…
- Calcium in fruit is important BUT
  - There is no reliable way to ***increase calcium in fruit***
  - Nitrogen ***reduces fruit calcium***
  - Lack of ROI information ($$$)
- Fungicide management is clearly critical
  - Timing and rotation are important eg ***at flowering***
  - Rainfall matters

Fruit maturity

- Maturity (dry matter) at harvest is critical
  - ***Low dry matter*** → slow ripening, poor texture and flavour, increased rots, vascular browning.
  - ***High dry matter*** → happy consumers, reduced chilling sensitivity and faster ripening ***BUT*** rots, grey flesh and vascular browning may increase.

Dry matter varies within orchards, between trees and within trees

Less variable quality at retail →

increased sales

Should industry consider NIR grading ??

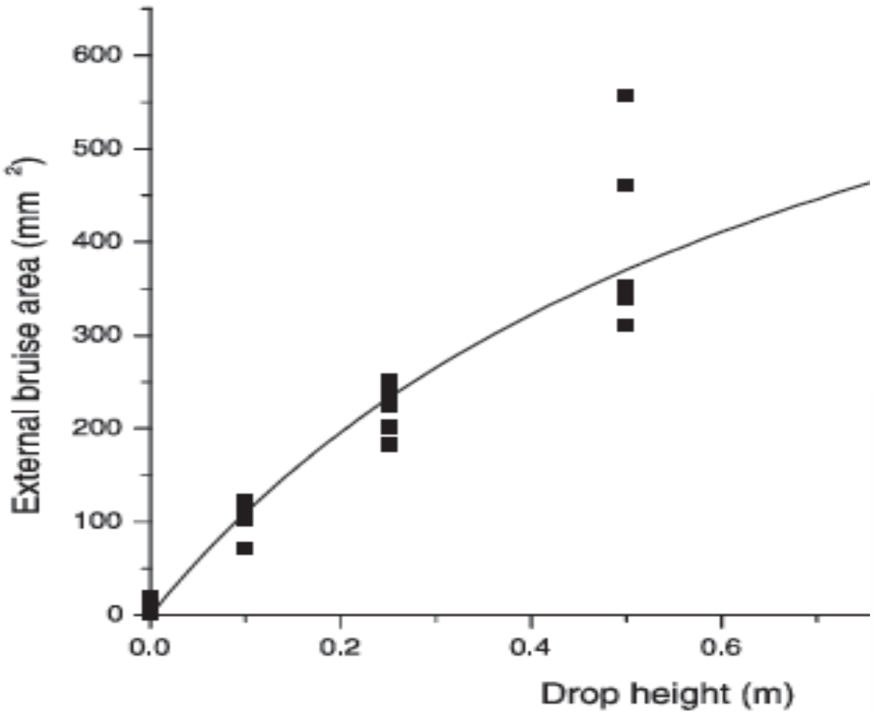
Harvest: Snap (pluck) v's clip ?

- Snapping vs clipping
  - NZ and South Africa clip
  - Snapping is quicker
- Willingham (AV01004) recommendation: Avocados can be snapped if
  - Trees not stressed
  - Fruit is not immature OR over mature (23-29% DM)
  - Fruit not harvested damp
  - Fruit not treated with Sunny (Uniconazole PGR)

Economic viability: Clipping reduces rots, doubles cost

Bruising: farm and packhouse

- Hard avocados are susceptible to bruising

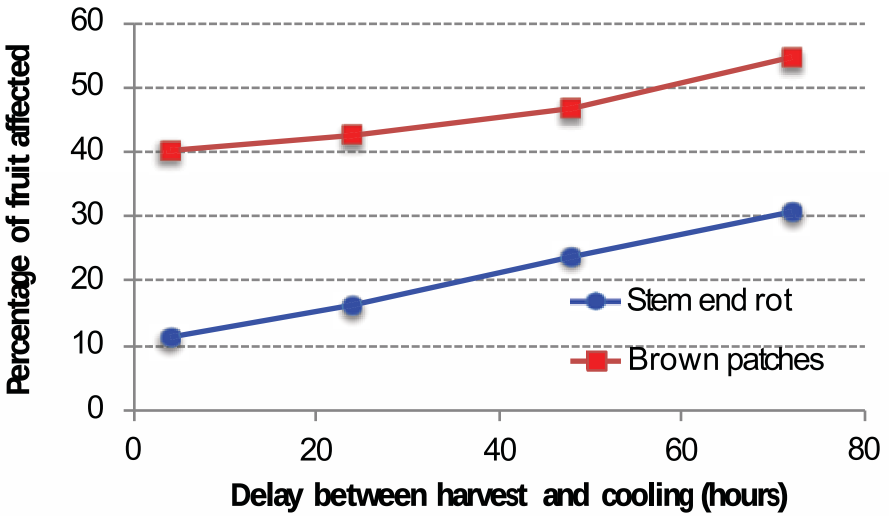


Derived from Mandemaker et al, 2006.

ALL fruit drops should be minimised

Pre-cooling

- Avocados don't ripen on the tree because of the "***tree factor***"
  - The tree factor degradation affected by temperature + time
- ***Variable temperature → variable ripeness at retail***

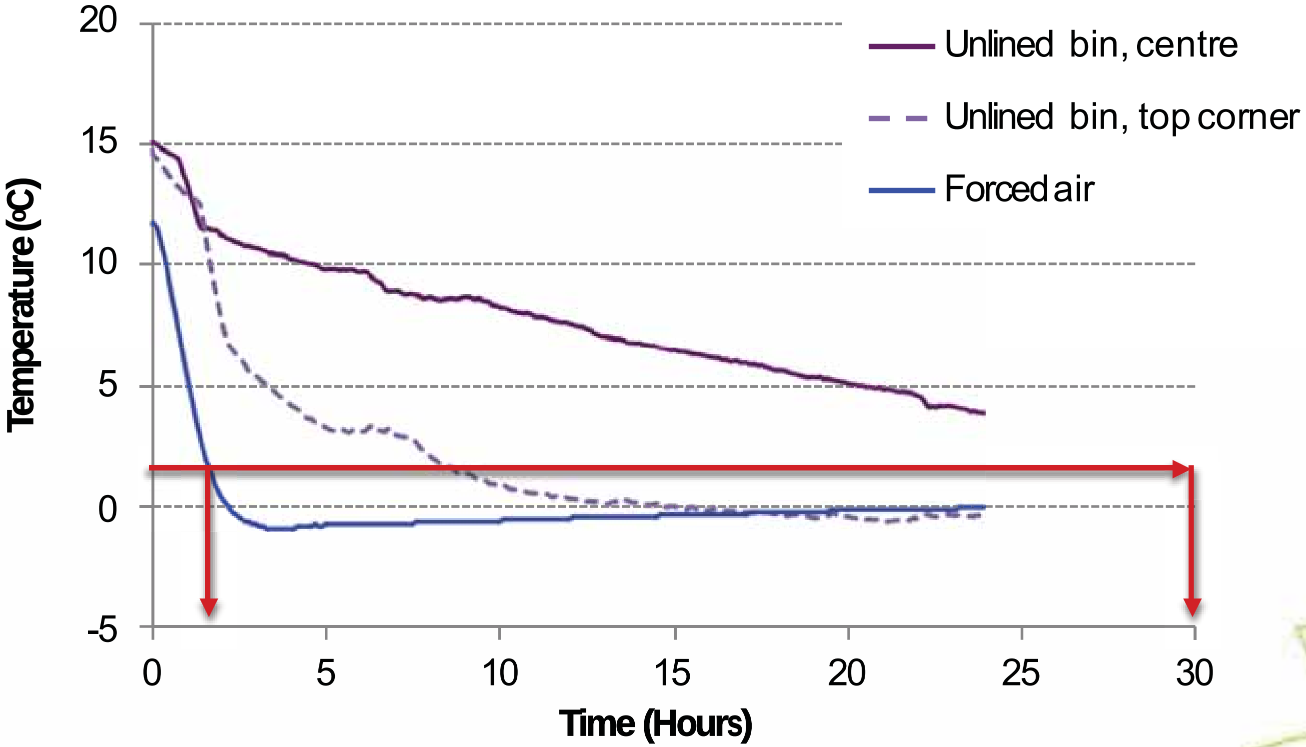


Fruit that stays warm after harvest is more likely to develop rots and internal discolouration, lose weight, ripen faster

Temperature variability in bins

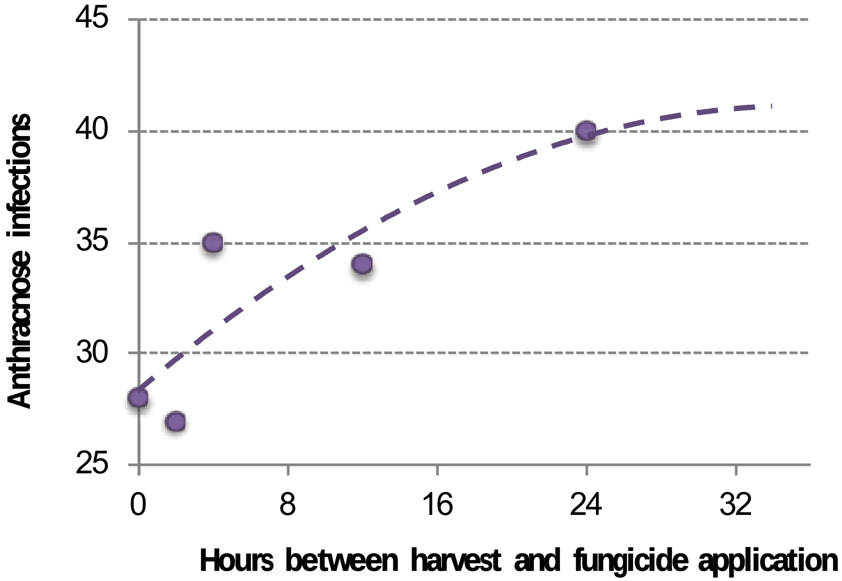
How warm are avocados in the centre of bins?

Temperature variability → more variability in ripeness



Postharvest fungicides

- ***Postharvest fungicides can reduce rots by approx 20 to 50%***
  - If this is from 90% to 70% so what?
  - Timing likely to be critical for infections at harvest eg SER
  - Less effect on pre-harvest infections
  - Results with SARs so far disappointing
  - Thyme oil?



Derived from Everett, 2012

Potential postharvest treatments

- ***Surface coatings can reduce moisture loss and improve both appearance and shelf life***.
  - Surface coatings modify the internal atmosphere
  - Add fungicidal compound (thyme oil?) for improved effect
  - Carnauba wax reduced chilling sensitivity
- ***SmartFresh – 1-MCP***
  - Delays ripening, allowing extended low temperature storage (42d @ 5°C)
  - Reduces chilling sensitivity
  - Used by South Africa
  - Variable ripening after treatment is the biggest issue

SmartFresh

4 weeks

7 weeks

4 or 7 weeks at 5.5°C + 1d @20°C. *From Woolf et al., 2005*

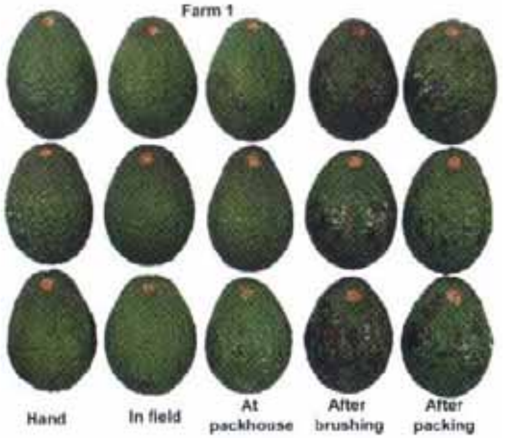
Potential postharvest treatments…

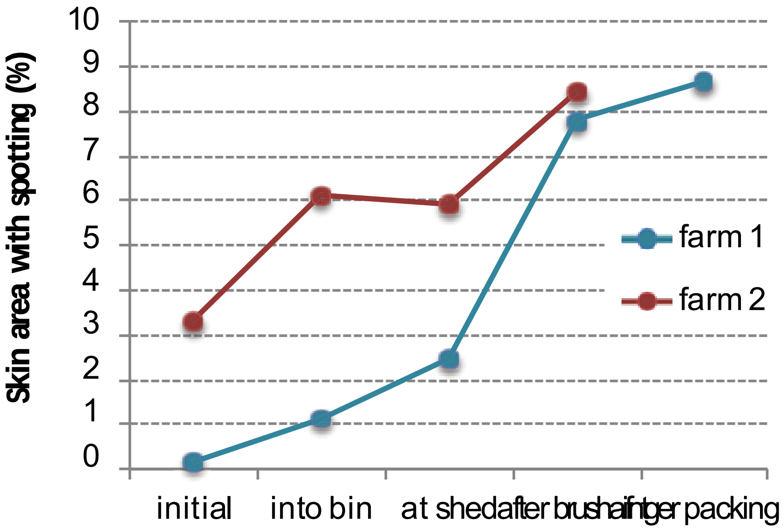
- ***Heat treatment***
  - May protect against chilling injury during cold disinfestation
  - Relatively narrow band of time / temperature combinations
- ***Low temperature conditioning***
  - Staged cooling over several days or weeks
  - Results variable!
    - Hofman 2010
    - Marques et al 2010

Woolf, 1997

Grading and packing

- Fruit may need washing, but should not be packed wet
- Brushes on packing lines can jostle fruit
  - Increase lenticel damage, spotting
- Dropped trays = bruised fruit
- Packing fruit while cold reduces bruising





Hofman, 2005

Grading and packing

- ***Sorting using Near Infrared Spectroscopy (NIR)***
  - Segregate fruit based on dry matter → ***less variability in ripeness***
  - Detects bruising and internal rots → ***less defects at retail***
  - **In-line sorting could reduce variable ripening**

James Cook University

Grading and packing – key points

- ***Uneven temperature management*** likely contributes to variable ripening and quality issues
  - Improve pre-cooling
  - Reduce harvest to pack times
- ***Postharvest fungicides*** applied more than 24h after harvest are probably a waste of money
- ***Surface coatings*** are not just a pretty face
- ***Optimise packing lines*** to minimise bruising and skin damage

NIR could segregate fruit by DM and thereby reduce variability

Cooling and storage

- ***Warm fruit loses moisture. Fast cooling after packing is essential.***

> *Product can deteriorate as much in 1 hour at 25°C*
> *as in 1 week at 1°C*

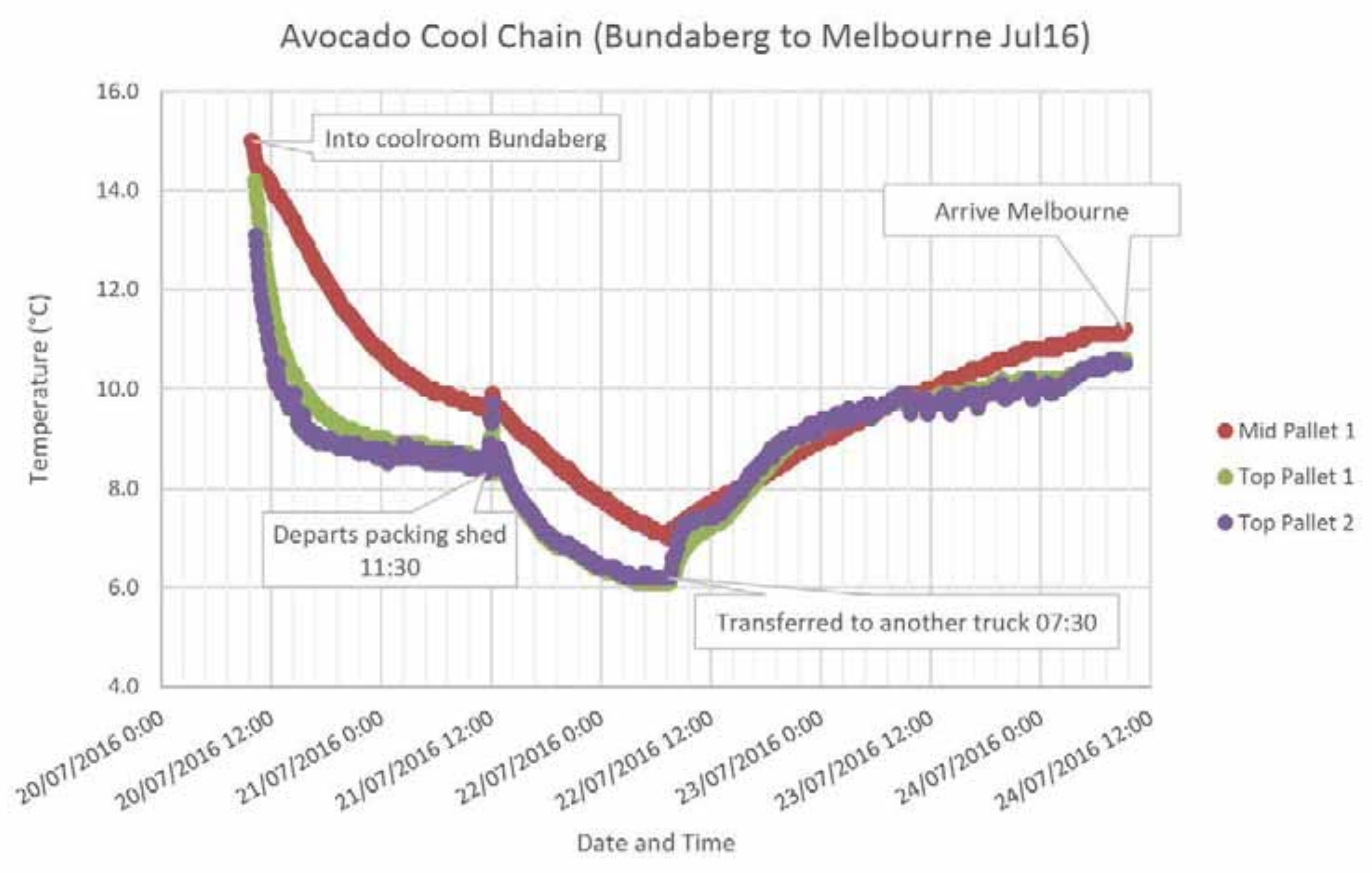
- ***Delays in cooling allow fruit to start ripening.***
  - Increased chilling sensitivity
  - Increased rots
  - Variable ripeness at retail
- ***Room cooling is very slow***, 0.5°C per hour
- ***Forced air cooling is 3 to 8 x faster***, 2°C per hour

Cooling and storage

Breaks in the cold chain can have a major impact on quality

Break of only 5 hours can increase rots

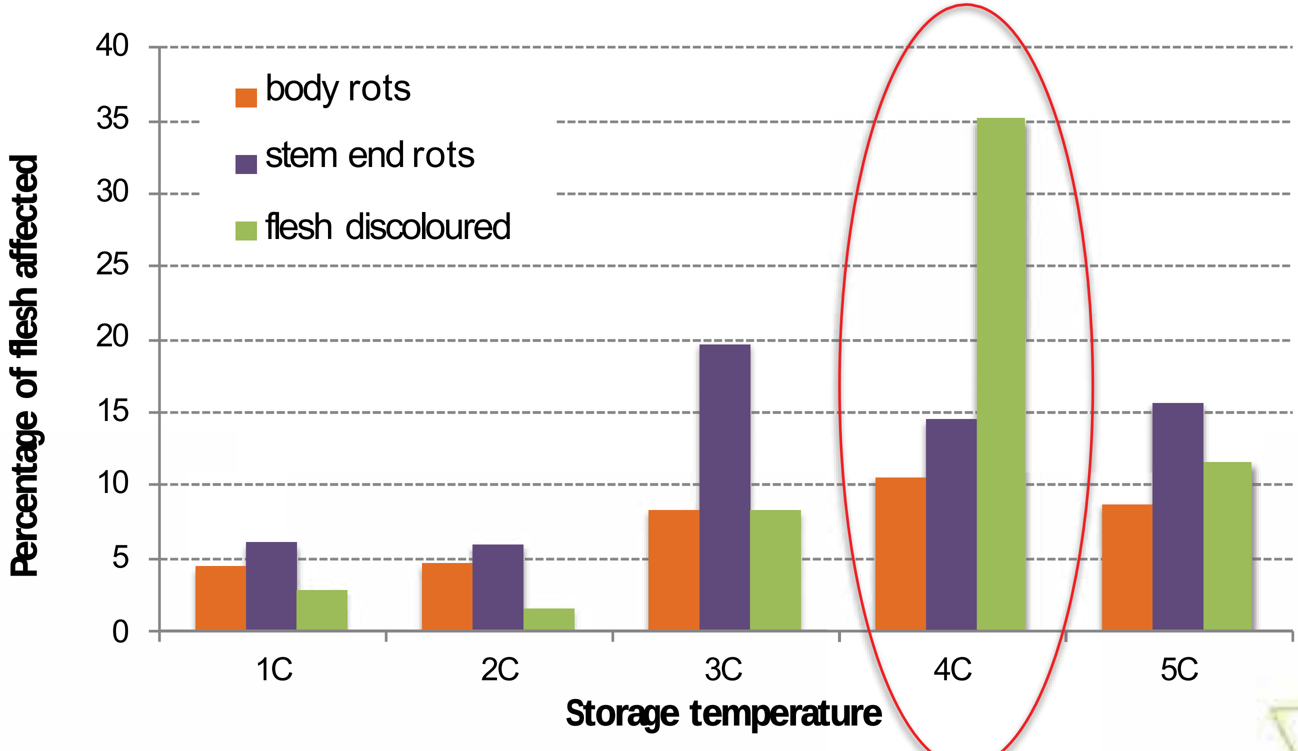
The longer that fruit has been stored, the bigger the effect of a break



Cooling and storage

- ***Concept of Killing Zone***

Derived from Hofman et al, 2010



Pre-conditioned at 6 °C for 3 days, then stored at 1 to 5 °C for 31 days, ripened at 20 °C

Cooling and storage

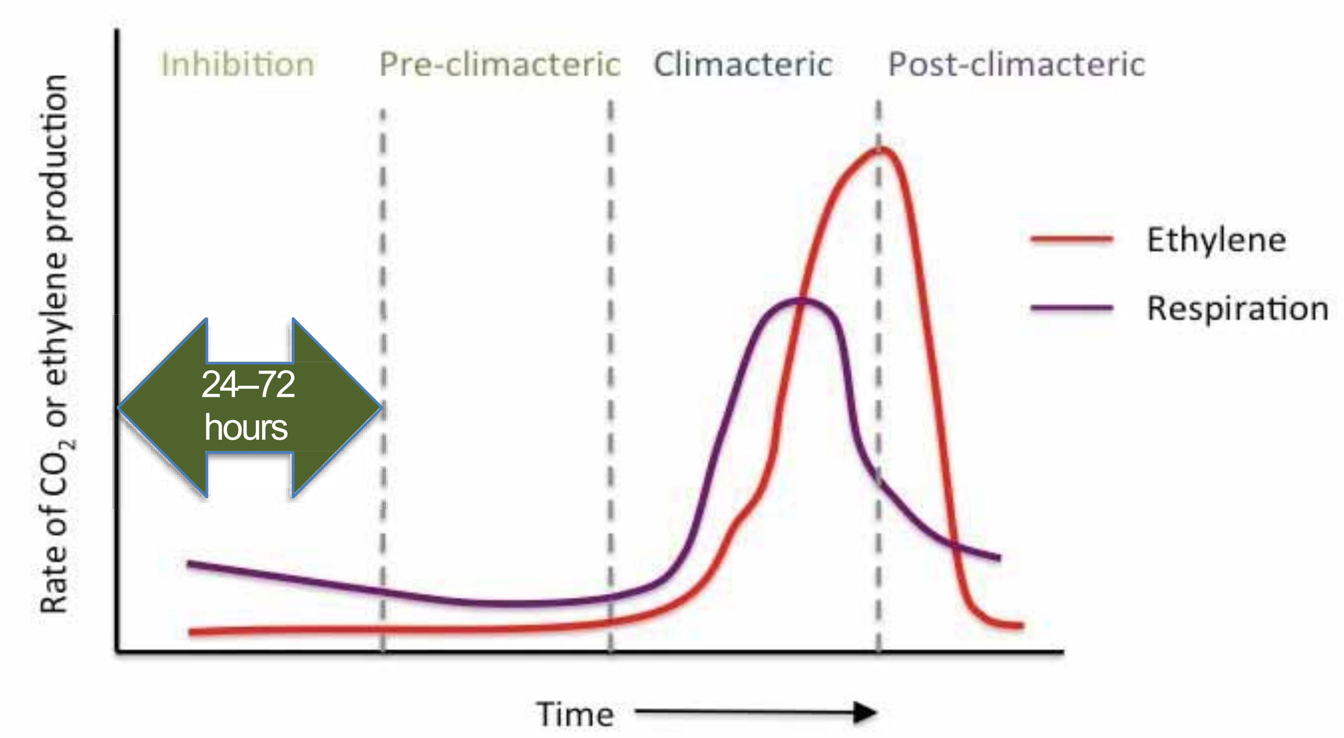
- **Removing ethylene** from the storage environment can increase storage life
- **Controlled atmospheres** can also improve storage life
- **Fruit should not be more than 30 days old when ripe**
  - Anti-fungal compounds in fruit decline during storage
  - Stem end rots advance
  - After 4 weeks incidence and severity of rots markedly increases

Cooling and storage – key points

- ***Ripening initiated in storage –>*** increased variability and CI
- ***Australian supply chains can be variable***
- ***Poor temperature control →*** variability and increased fruit rots
- ***Ethylene monitoring / removal***
- ***Transport at 5^{o}C?***

Ripening

Once it starts, ripening is unstoppable



Ripening

- ***Triggering with ethylene*** reduces variability in ripening
- ***Dry Matter*** content critical to ripening time
- ***High temperatures*** increase the rate of ripening but reduce quality
  - Temperatures of 15-17°C result in best outturn quality
  - Ripening at 20°C increases rots and reduces saleable life
- ***Ripened fruit need to be held to allow for distribution and retail***
  - Rubbery store at 2°C
  - Soft: store at 5–8°C

Rubbery-sprung Sprung-softening Softening-firm

Fruit quality after 7 days at 2 °C

Ripening – key points

- ***Fruit may be ripened at higher temperatures to meet supply chain requirements – but this will reduce quality at retail***
  - Are wholesalers monitoring ethylene and CO_2 during ripening?
  - Are rooms temperature managed?
- ***Woolworths specify***
  - Receival temperature of 5 to 9°C – should this be reduced?
  - Packed + 7 days – could be increased?

Review of resources

- ***Australian and international avocado best practice resources were reviewed***: online and hard copy
  - Content
  - Structure
- ***Also looked at other industry resources***: grapes, vegetable, mango, pear, banana

Low temperature effects

Freezing damage

Most vegetables freeze at just below 0°C. Freezing damages cells, allowing the contents to leak out. Tissue that has been frozen can have a water-soaked or dehydrated appearance.

The temperature at which products freeze is a function of the concentration of dissolved solutes —such as sugar—within the cells. Pure water freezes at 0°C. A product such as lettuce, which is

Snails

It is easiest to kill snails while they are still on the ground. So it is important to be monitorin vineyard floor during early spring and bait where needed. This provides the best opportunit prevent snails moving up into the developing vine canopy and contaminating fruit at harves

There are two types of chemical baits available -

- Methaldehyde (either grain bran or Durham) - (Green)
- Methiocarb - (Blue)

Best Practice

Although more expensive, the Durham, wheat-based pellets are longer-las because they are moisture resistant and do not disintegrate when wet.

AAL Best Practice Online Resource

- ***Most of the content is there***, but difficult to find the key messages
- ***Suggestions***:
  - Make website interface more intuitive
  - Highlight key points at start of sections, and reduce areas of solid text
  - Reorder content to flow in order of the supply chain
  - Update self-assessment tool – more interactive with videos and photos
  - Keep messages simple – e.g. don't drop fruit (instead of don't drop more than 30cm)
- **AAL website and BPR currently being revised**

Gaps in Australian resources

- ***Growing*** – needs pre-harvest management of fruit disease section
- ***Harvesting*** – needs a separate module
- ***Packhouse*** – more detail required on cooling, temp management and fungicide treatments
- ***Transport*** – effect of breaks in the cool chain
- ***Wholesale*** – stock rotation and importance of fruit age
- ***Ripening*** – consistent stages of ripeness
- ***Retail*** – more concise and aim at relevant retail staff

Resources needed

- ***Growing***
  - Develop a single growing guide that includes all the information from the online best-practice resource
- ***Cool chain*** (harvest to wholesale/ripening) BPguide and supporting resources:
  - Temperature management at harvest, cooling, packing, transport and ripening
  - Management of fruit age
  - Temperature monitoring in the supply chain
  - Effects on quality and storage life of breaks in cool chain or delays in cooling
- ***Retail***
  - New manual as part of AV15011

Comparison of key practices

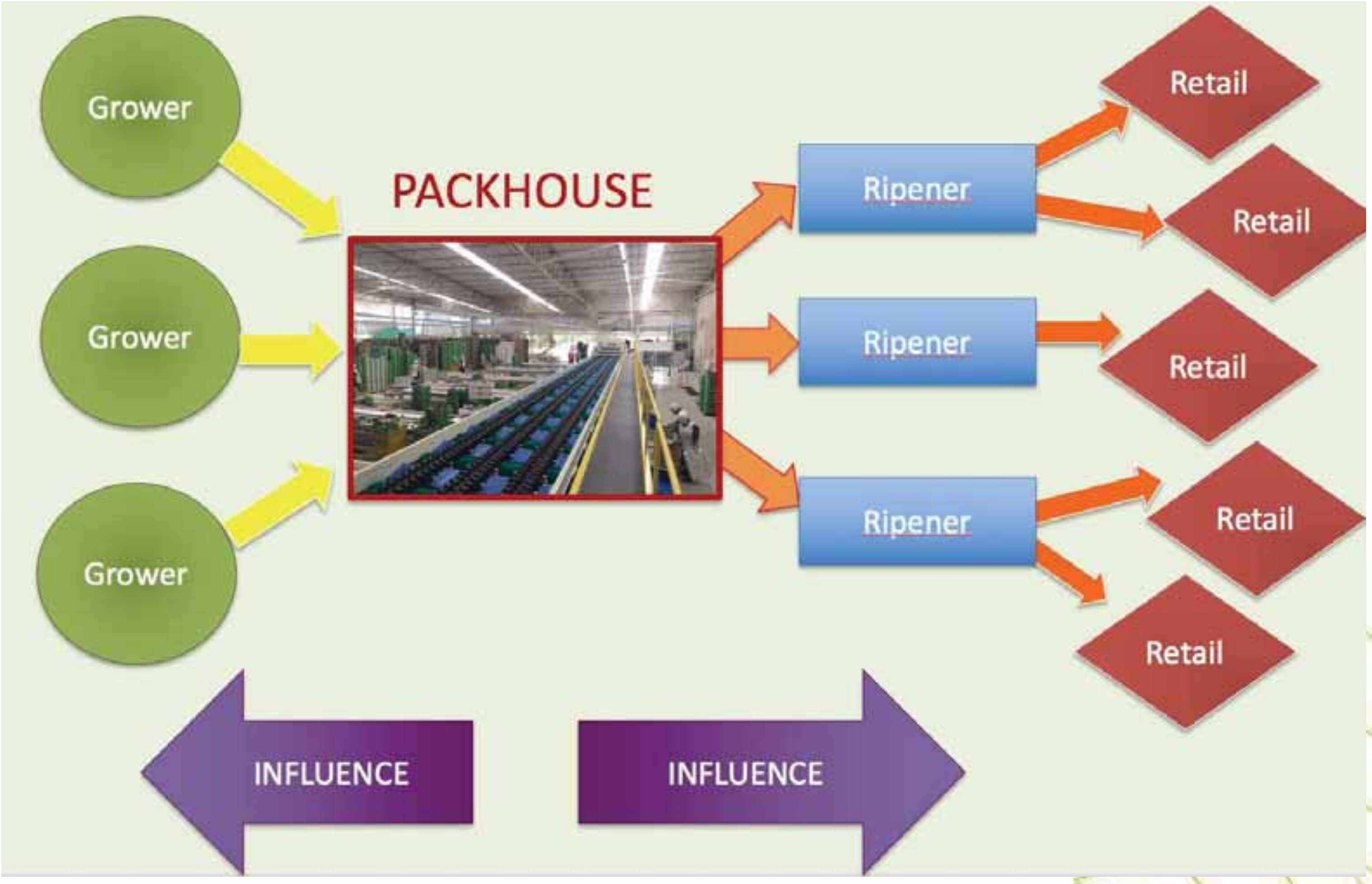
Practice	Best practice	Australia	New Zealand	USA	South Africa
Packhouse					
Postharvest fungicides	Gap – Prochloraz effects are inconsistent . Thyme oil promising	Not mentioned in resources, but Prochloraz used	None – market issues with Prochloraz		
Timing of fungicide	<24hrs after harvest	NA	NA		At harvest
Time from harvest to packing/precooling	Pick and pack/cool to 5ºC within 24hrs	Within 6hrs of harvest	Pick to pack within 48hrs	8hrs ideally	2hrs ideal 12hrs max
Precooling?	Forced-air with flow rate of 0.5–2.0 $L.kg^{-1}.sec^{-1}$ or hydrocooling	Forced-air recommended 5-7ºC	None – room cool after packing	Yes, hydrocooling to 5ºC with chlorine	Recommend forced air or hydrocooling
Cooling after packing	Forced-air if not precooled	Forced-air if not precooled	Room cooling to 5.5ºC – keep records	Maintain 5ºC	
Waxing	Gap Can reduce weight loss and increase shelf life	No	No		Yes – within 48hrs of harvest (Avoshine® and Carnauba wax)

Key supply chain issues

- ***Variability in ripeness***
  - Temperature management, from harvest to ripening: Improve
  - Dry Matter variability – reduce by grading with NIR?
  - Ripener skills
- ***Body rots in fruit***
  - Pre-harvest fungicide management eg applications during flowering
  - Postharvest fungicides – are they effective?
  - Cooling after harvest and packing
  - Temperature management during transport and storage
  - Fruit age (Erratic ordering / top ups)

PACKHOUSES ARE THE INFLUENCERS

Practice change: *Focus on the packhouse*



Next steps: Engage with packhouses

Task 6: Audit of current practices across the supply chain to ID issues and barriers to adoption.

Our plan: Revise the activity to work with 12 major packhouses to:

- **Establish working relationships** with packhouses.
- **Audit and GAP analysis** of each packhouse
- **Review supplying grower practices** to ID key issues
- ***Monitor supply chain temperatures*** (***12 x 10 – encourage ALL***)
- **Work with retailers** – keep engaged
- **Build on AAL/QDAF** packhouse/ripener audits
- Agreed **improvement plan:** ***BPRs, training, support***

Next steps: Revise Best Practice Resource

Task 7: Refresh best practice resources

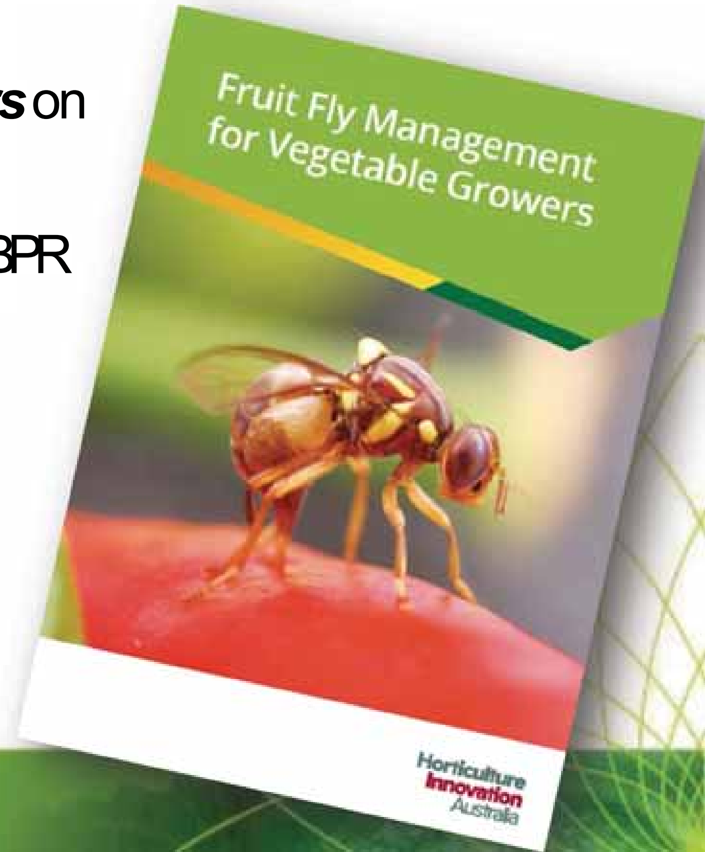
1 Consult **QDAF** and **AAL** on a ***unified approach***

2 ***QDAF to produce critical control point BPR*** (Peter Hofman and Daryl Joyce)

3 ***Consult with packhouses, growers and retailers*** on BPR needs

4 **Produce an agreed BPR** (concise, easy to use) BPR with the clear, agreed targets.
Refer Fruit fly BPR example.

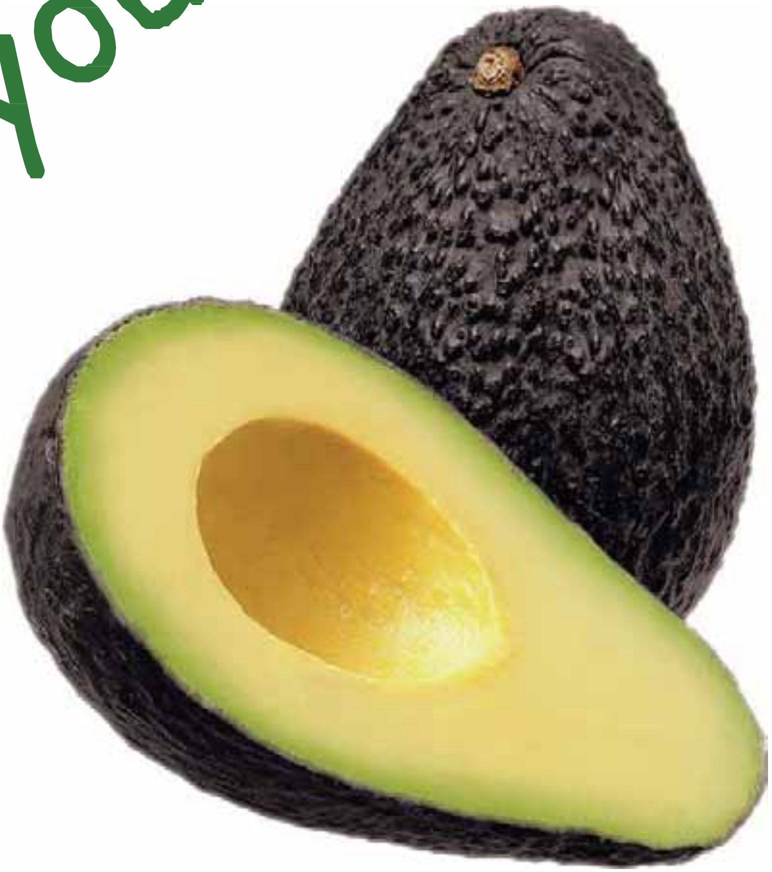
5 **Deliver** supporting video, E-learning training etc.



Specific items for discussion

- Identify the 12 packhouses?
- Approval to modify Tasks 6 and 7 as described
- Preferred format of BPR(s) + support materials
- Accreditation system for packhouses
- Review dates for milestones (esp task 6)
- Measurement of impact – when and how to do it effectively?

Thank you



Project objectives and activities

Objectives

1. Increase the adoption of best practice in cool chain management and postharvest handling across all sectors of Australian avocado supply chains from orchard to retail
2. Reduce the incidence of body rots and other quality defects in avocado fruit (25 → 10%)
3. Increase the awareness across the supply chain of factors that predispose fruit to quality defects

Activities

- **Task 2.** Review Avocado postharvest research in Australia and internationally (Months 2-3)
- **Task 3.** Review current resources available to the avocado industry in Australia and overseas (Months 3-4)
- **Task 4.** Identify factors that pre-dispose fruit to internal rots, from orchard management forward throughout the supply chain (Month 5)
- **Task 5**. Review current and potential developments in chemistry and practices for managing avocado postharvest disease (Months 6-7)
- **Task 6.** Conduct an audit of current practices across the supply chain to identify barriers to uptake of best practice
- **Task 7.** Refresh best practice resources for all sectors of the supply chain and publish in a format most suitable to supply-chain stakeholders in each sector from grower to retailer (Months 8-12)
- **Task 8.** Develop and implement a change program across the supply chain for uptake of best practice by all sectors from orchard to retail (Months 12-18)

Avocado supply chain quality improvement (AV15010)

Outline

- Project overview
- Summary of activities to date
- Best practice resources
- Implementation/roll-out
- Feedback/discussion

Project objectives

Objectives

1. Increase the adoption of best practice in cool chain management and postharvest handling across all sectors of Australian avocado supply chains from orchard to retail
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Approach

Review
- Postharvest research
- Best practice resources

Refresh resources
- Best practice guide
- Problem solver guide

Initial industry consultation

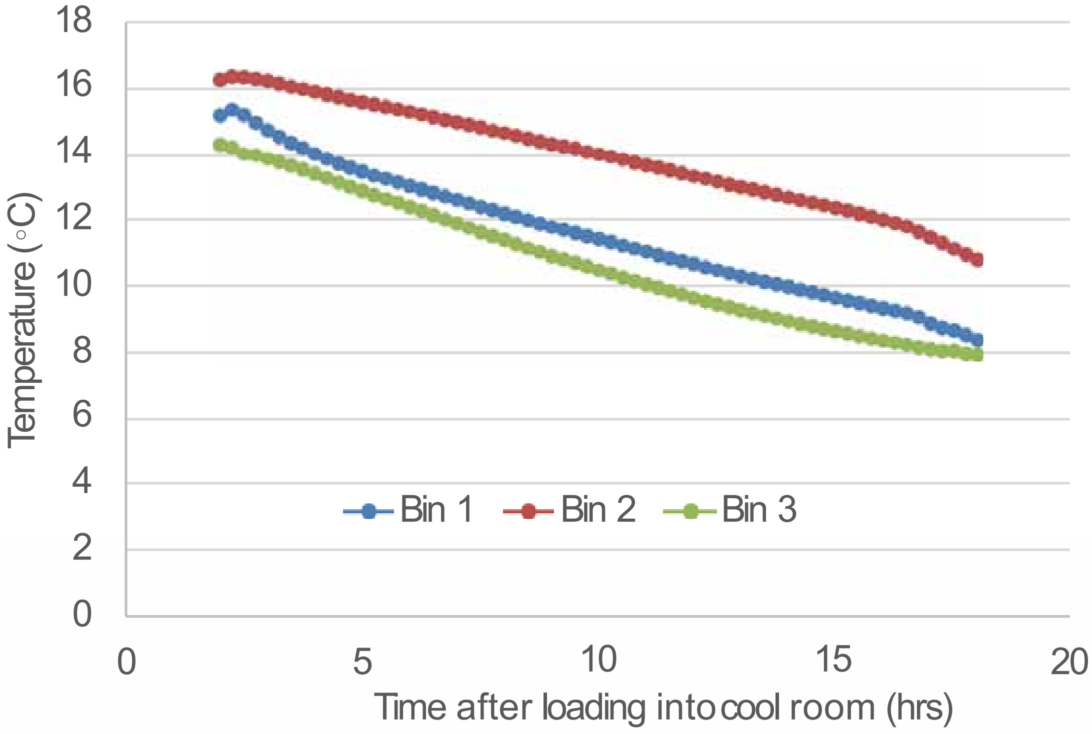
Packhouse studies
- Identify issues
- Best practice recommendations

Implement change program
- Training and resources

Cool chain studies

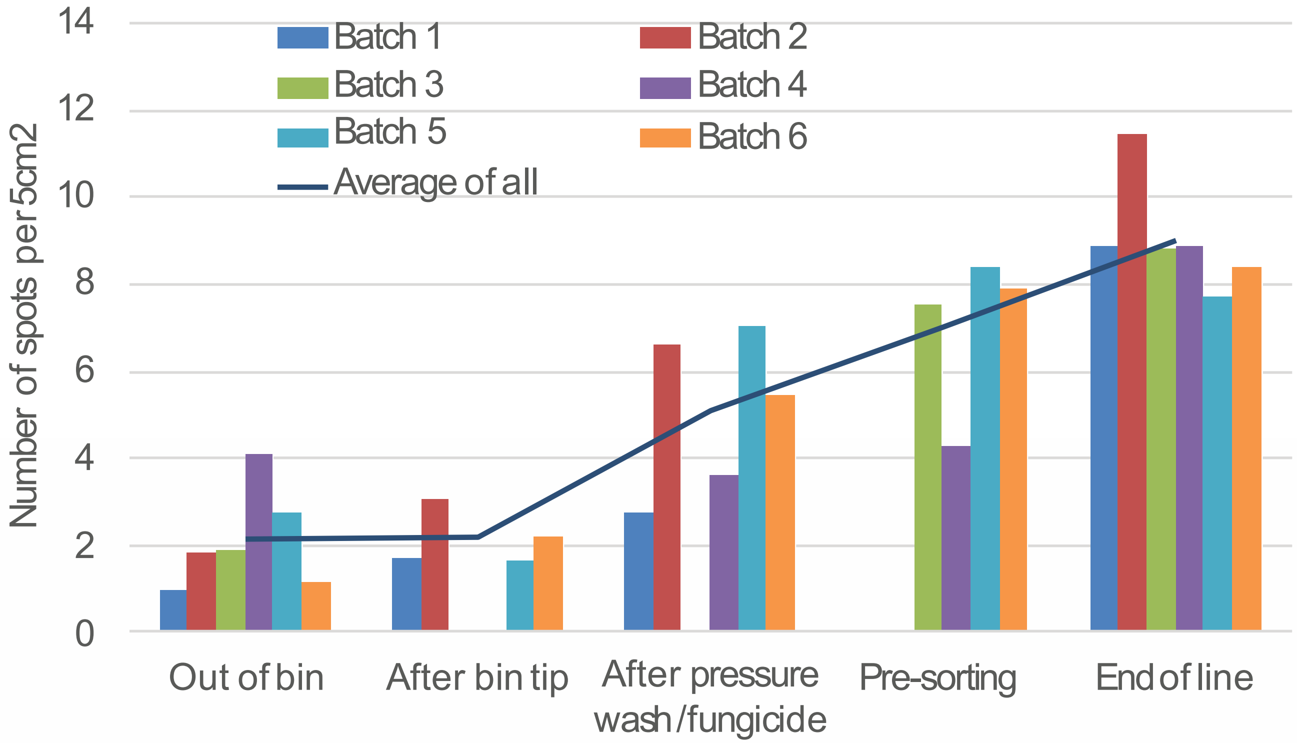
- Logging temperatures from harvest to retail
- Assessing packhouse operation
  - Impacts and fungicide application
- Comparing quality at:
  - End of pack line
  - Dispatch from ripener
  - Retrieval from retail store
- Feedback report with results

Temperatures: harvest to packing

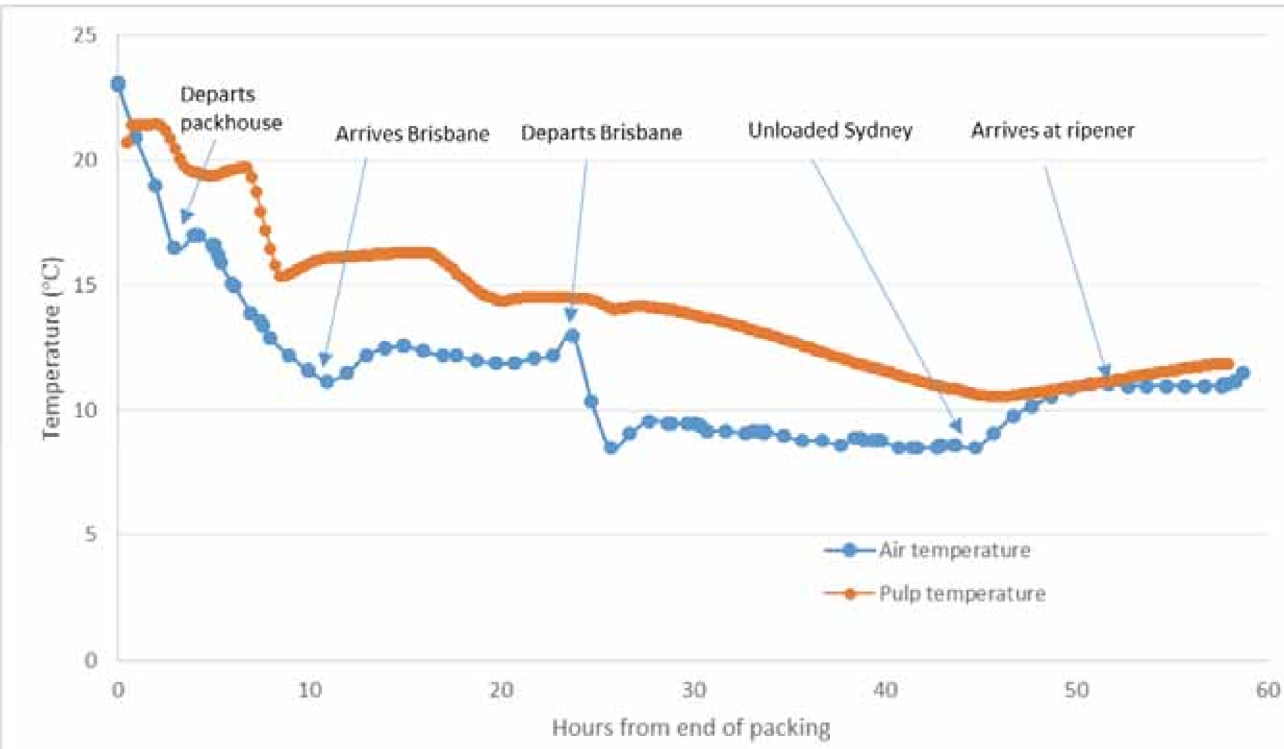


Packing operations

Lenticel damage at points along the packing line

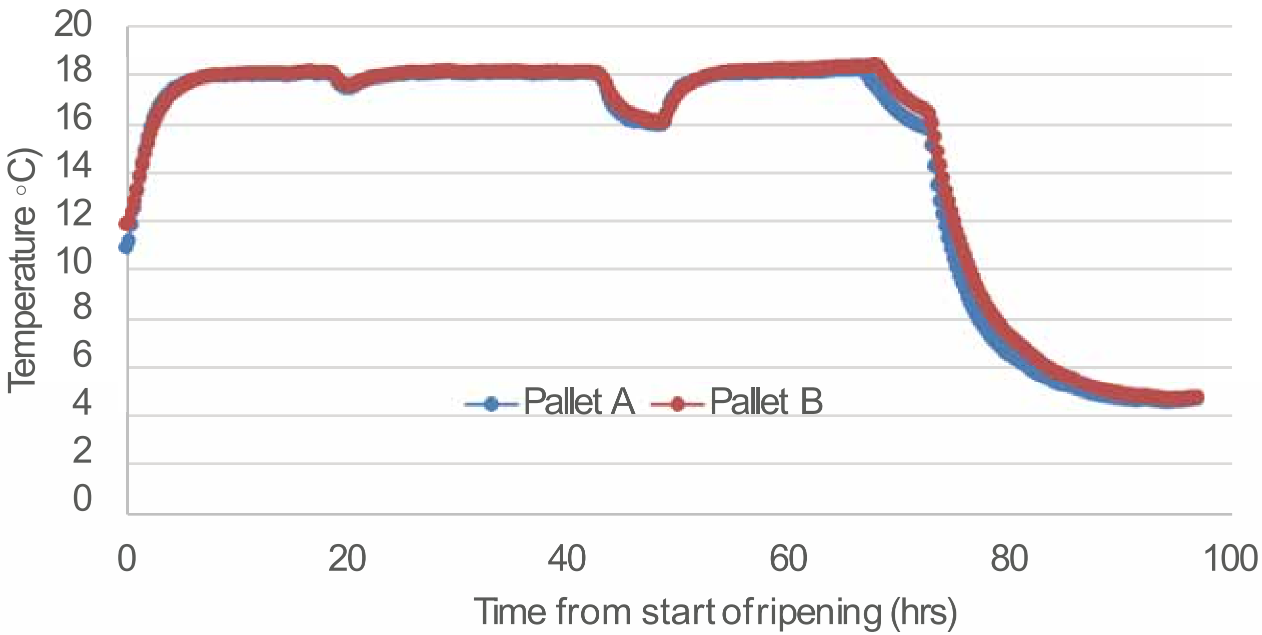


Temperatures: Packhouse to ripener

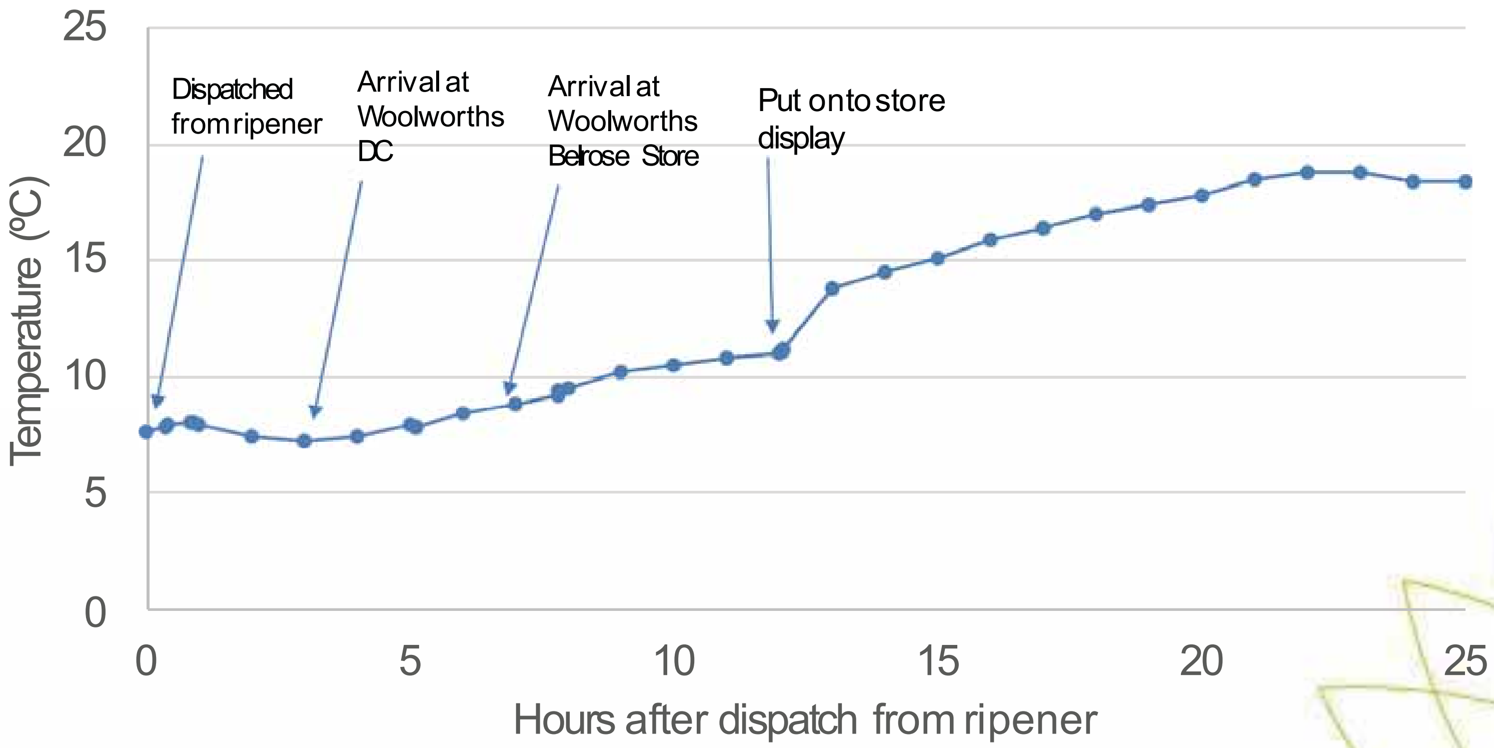


Temperatures: Ripening

- Pulp temperatures:



Temperatures: to retail



Quality assessments

	Number of fruit with internal flesh damage at soft-ripe (n=20)	
Supply chain stage	Packhouse A	Packhouse B
1. Taken direct from packhouse, stored 5 days, ripened	1	1
2. At dispatch from ripener in Sydney	1	5
3. Retail store	0	6

Cool chain studies

- Logging temperatures from harvest to retail
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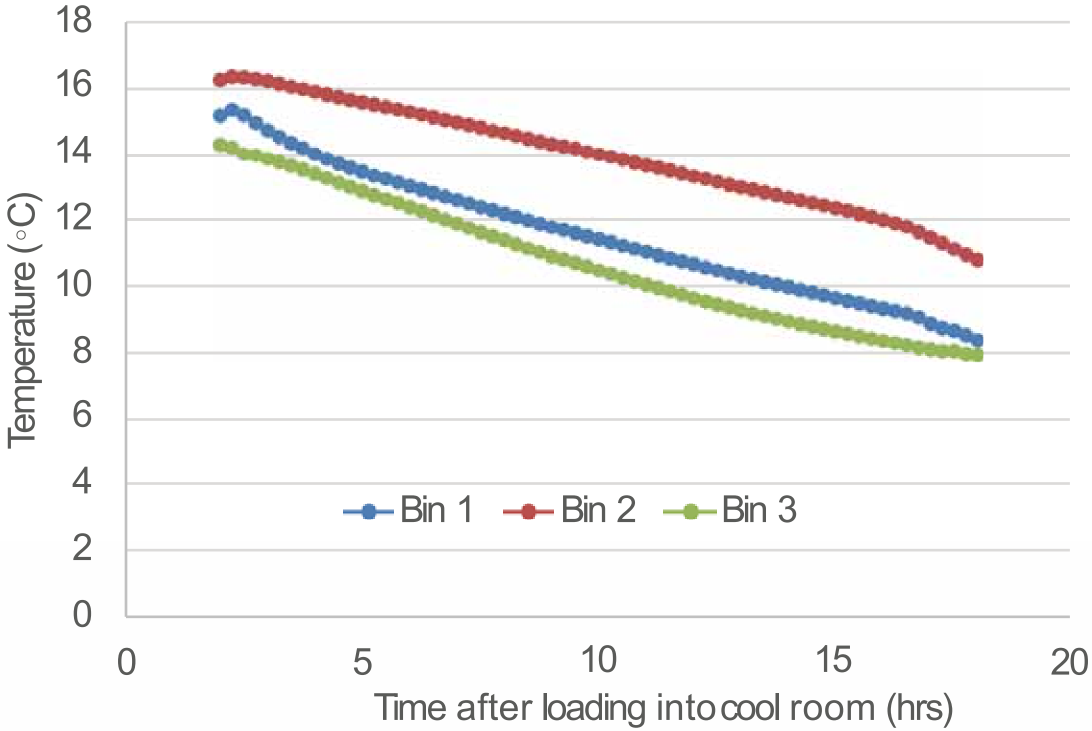
Temperatures: harvest to packing



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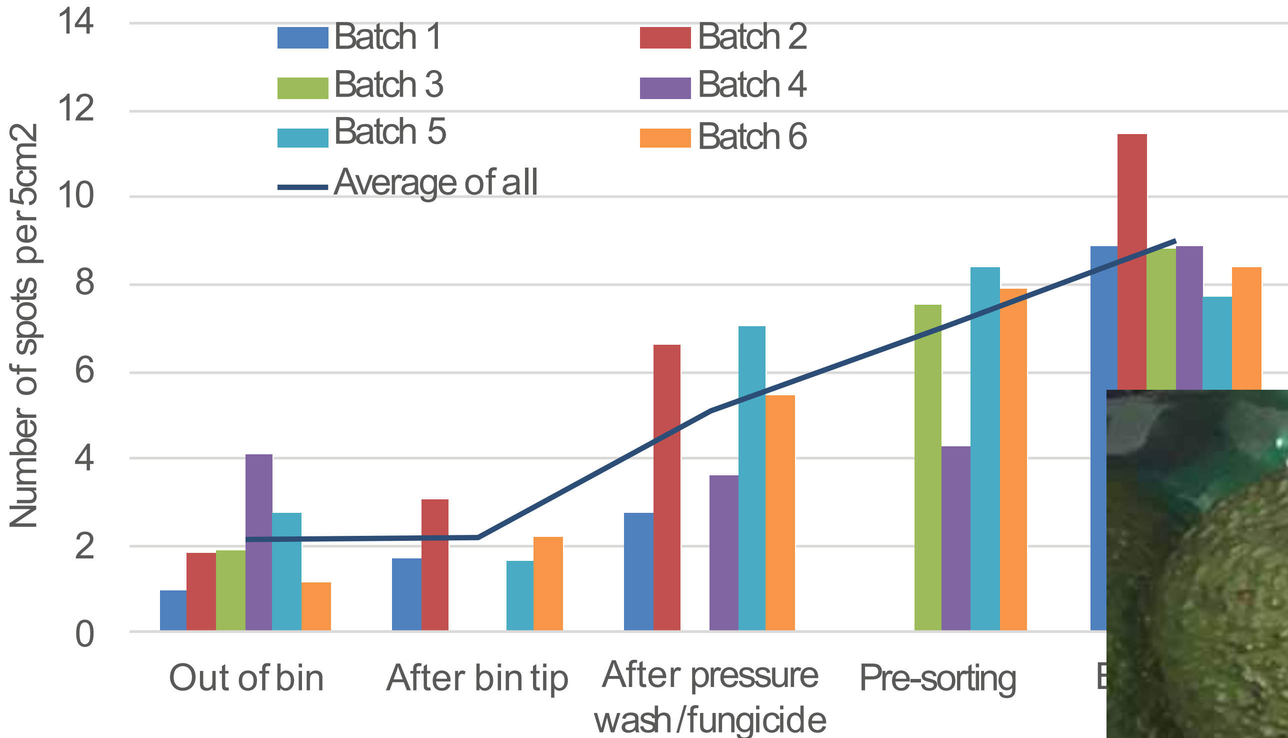
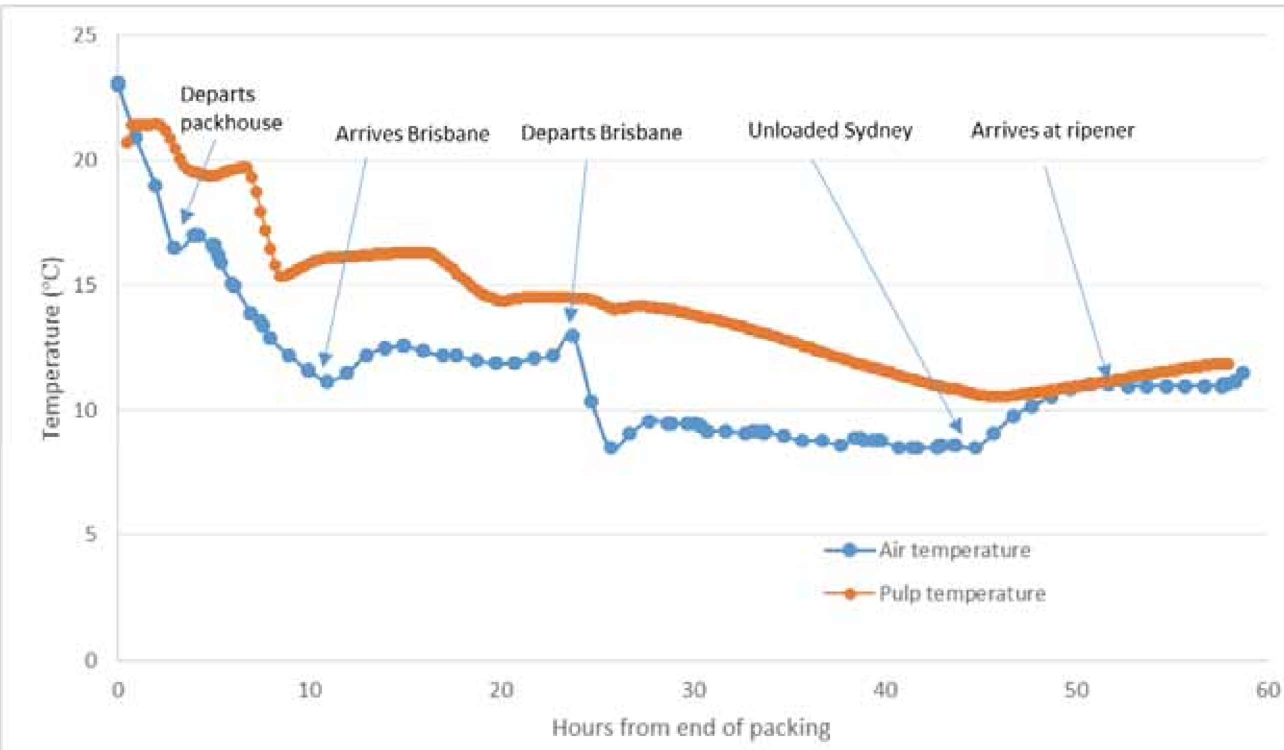
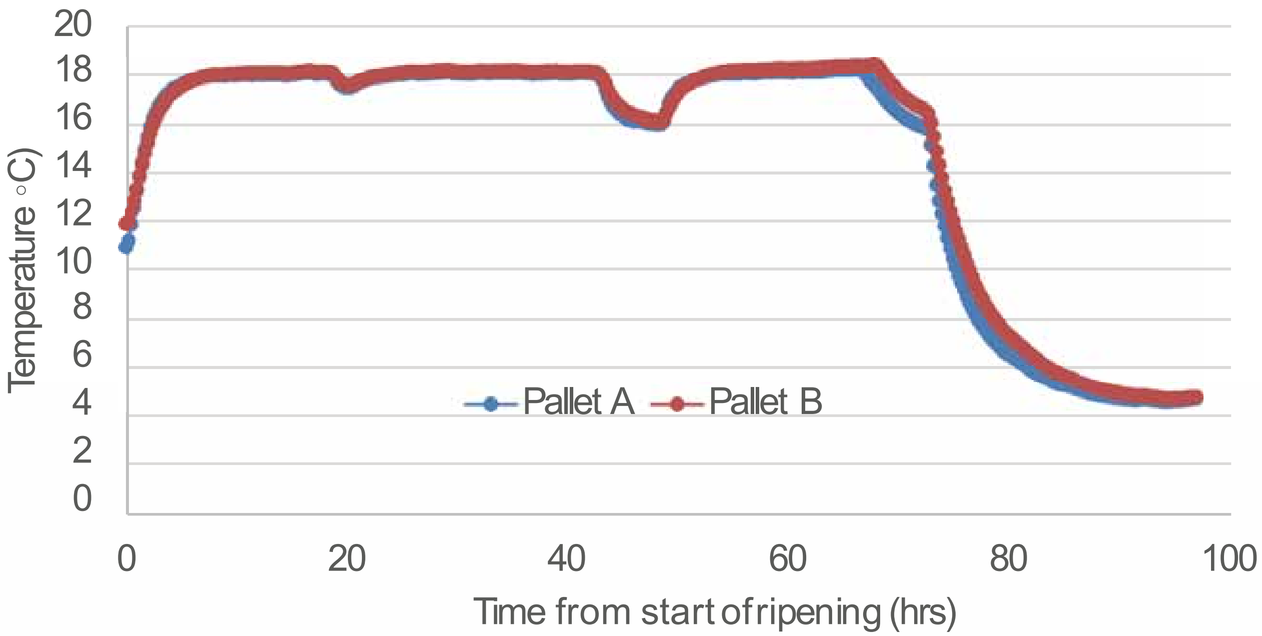


Temperatures: Packhouse to ripener

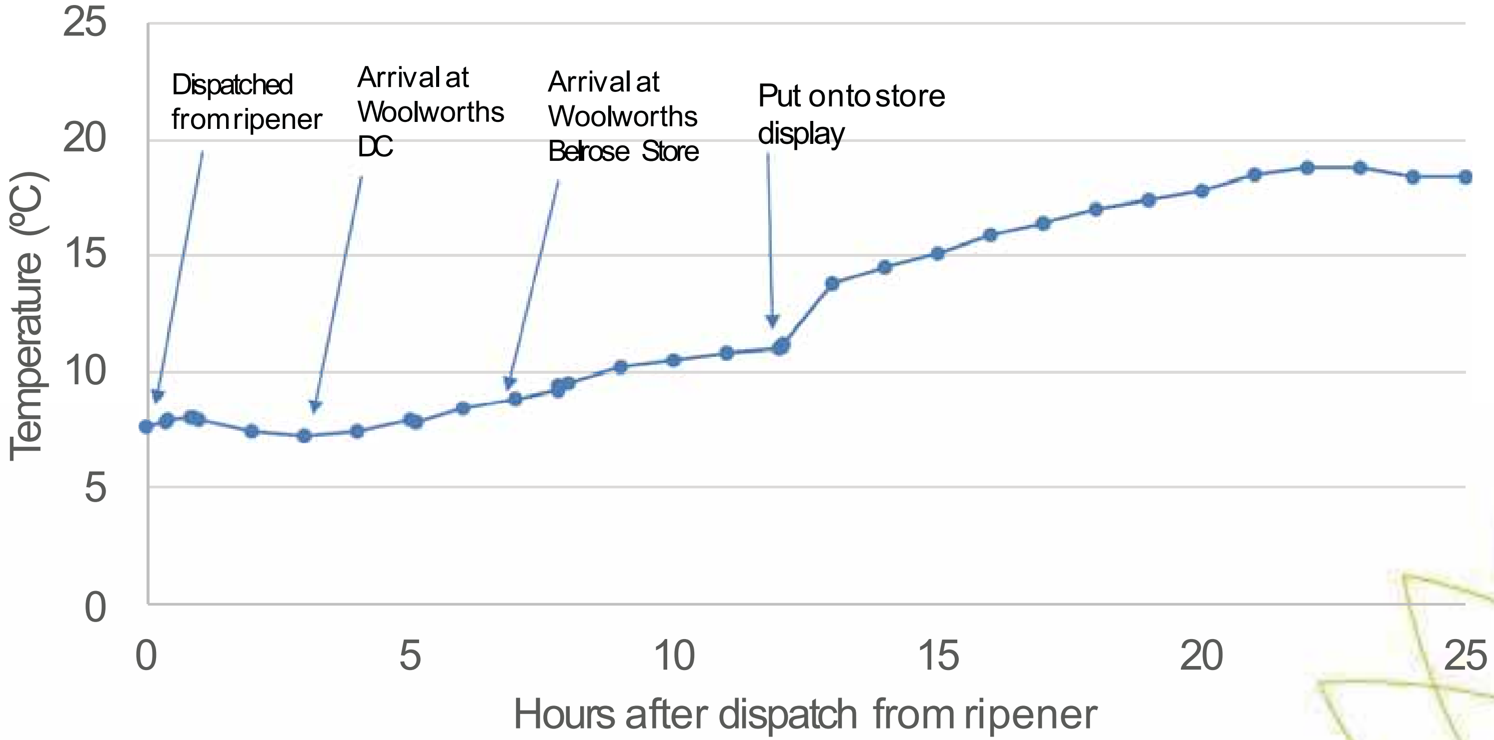


Temperatures: Ripening

- Pulp temperatures:



Temperatures: to retail



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Mission Produce supply chain visit

- John and Mark Baker (PMA) visited in June - report available
- ***Mission Produce goals:***
  - ***Pick to pack: 24 hours***
  - ***Pick to retail shelf : 30 days (all countries, all markets)***
- ***Focus:***
  - ***Temperature management***
  - ***Soft drops in pack houses***
  - ***Minimal handling***
  - ***Fruit age***

Best practice resources

1. Avocado quality best practice guide (office use)
2. Avocado quality problem solver guide (office use)
3. Checklists/summary guide (field use)
4. Review: Pre and postharvest management of avocados (reference)

Guides to be printed, and made available on the AAL online BPR

1. Avocado quality best practice guide

Harvest

Key points

- Only harvest fruit once it reaches minimum dry matter content
- Harvest dry fruit
- Avoid dropping or bouncing fruit
- Cover fruit in bins to keep cool and reduce sunburn

Prepare for harvest

- Check the operation of harvesting, grading and packing equipment and of cool rooms before the start of harvest, and fix/adjust as needed.
- Clean bins and check suspension on bin trailers / runners.

When to harvest

Fruit need to reach minimum maturity levels to ripen properly and eat well. Dry matter is an excellent indicator of fruit maturity. Test dry matter before picking;

Sample at least **20 fruit per block** from a **minimum of five trees**.

- Select equal numbers of fruit from each side of the canopy (eg east-west).
- Note that fruit at the top of the canopy and large fruit on the northern and eastern sides of the tree are likely to mature first.
- However, size and appearance are not generally reliable indicators of maturity.

Do not start harvesting until fruit meets minimum dry matter content;

- Hass >23%
- Shepard >21%
- Reed, Fuerte >20%

Dates from previous seasons can be a useful indicator when to start testing for maturity. However, maturation can vary from year to year, across blocks within the orchard, and between different cultivars and rootstocks.

Develop a harvest schedule based on maturity zones or blocks and provide clear instructions to pickers and supervisors.

Fruit picking

Hass can be **plucked**, other varieties must be **clipped**.

Hass is recommended to be clipped if;

- Humidity is high / weather is wet
- Fruit is not in the 23-29% dry matter range
- Trees have been stressed
- Growth regulators (e.g. Sunny®) have been used.

Fruit should be picked dry (*if possible*);

- Delay harvest for 48 hours after heavy rain (>20mm in 12 hours)
- Delay harvest for 24 hours after drizzle.

Wet fruit *is more sensitive to mechanical damage/abrasion, and to skin spotting (or lenticel damage), which will increase the risk of rots. If conditions are wet, apply postharvest fungicide ASAP (within <24 hours of harvest)*

Pick exposed fruit first, especially if daily temperatures exceed 30°C.

Careful handling and unloading will reduce fruit physical damage (e.g. skin spotting, bruising, flesh cracking) and the associated risks of diseases.

- **Minimise all fruit drops.**
- Train pickers and monitor them regularly to ensure they are handling fruit carefully.
- Use baffles in picking bags, raise cherry picker slowly.
- Minimise distance between bins and pickers.
- Check equipment for sharp edges or damage.

Bin handling

- Don't overfill field bins.
- Keep bins shaded as much as possible.
- Transfer bins from the field as quickly as possible once full, preferably within 30 minutes. Ensure drivers travel at maximum 20kph and access roads are kept in good condition to reduce fruit bouncing in bins.
- Keep bins in a shaded area on arrival at the packhouse to reduce heating and sunburn.

2. Avocado quality problem solver guide

Covers internal and external fruit defects, and ripening and storage issues

Grey/brown flesh (or diffuse discolouration)

What is it?

- Dark areas in the flesh usually grey to grey/ brown in colour and with poorly defined margins.
- Usually starts at the bottom and near the seed and spreads upwards and outwards.
- May be associated with vascular browning.

What possibly causes it?

- Storing or transporting fruit for too long at standard storage temperatures (e.g. greater than about 3–4 weeks at 5°C) before ripening.
- Holding fruit after ripening at too low a temperature (e.g. below 5-7°C) and/or for too long (e.g. more than 3 days for firm ripe fruit).

How can it be minimised or prevented?

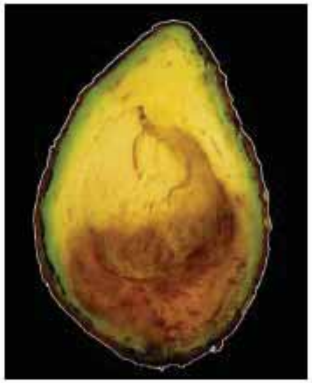
- Ensure effective temperature management measures after harvest as described in the fruit rots section.

Before ripening

- Do not store early-mid season fruit before ripening for longer than 14 days or less depending on fruit age and handling temperatures (see details on Table 2 in the 'Avocado Fruit Quality Best Practices Guide').
- Do not store late season fruit for longer than 5 days.
- Ensure ethylene level during storage is not too high, as it may trigger ripening and cause early onset of symptoms.
- Check fruit condition and length of time in storage daily; remove fruit if there is a risk of fruit starting to ripen.

After ripening

- Do not store Hass for longer than 7 days if at 'rubbery' stage, 5 days if 'softening', or 3 days if 'firm ripe'; do not store green skins for longer than 5 days if 'rubbery' or 3 days if 'softening' or 'firm ripe'.
- Check internal quality of ripened fruit held in storage daily and remove at first sign of flesh discolouration.



3. Checklists

Harvest

Harvest fruit when mature
•Hass >23% dry matter
•Shepard >21% dry matter

Sample at least 20 fruit for dry matter testing from >4 trees/block and opposite sides of the canopy

Pluck – Hass, **Clip** – other varieties

Pick fruit when dry if possible
If Hass fruit are harvested wet then clip stems instead of snapping, apply fungicide ASAP.

Pick exposed fruit first if daily temperatures are >30°C

Minimise fruit drops
Train pickers to empty bags carefully

Manage bins
•Keep filled bins shaded
•Don't overfill
•Transfer to packhouse ASAP BUT max. speed 20kph

Receival

Aim to pack within 24 hours of harvest.

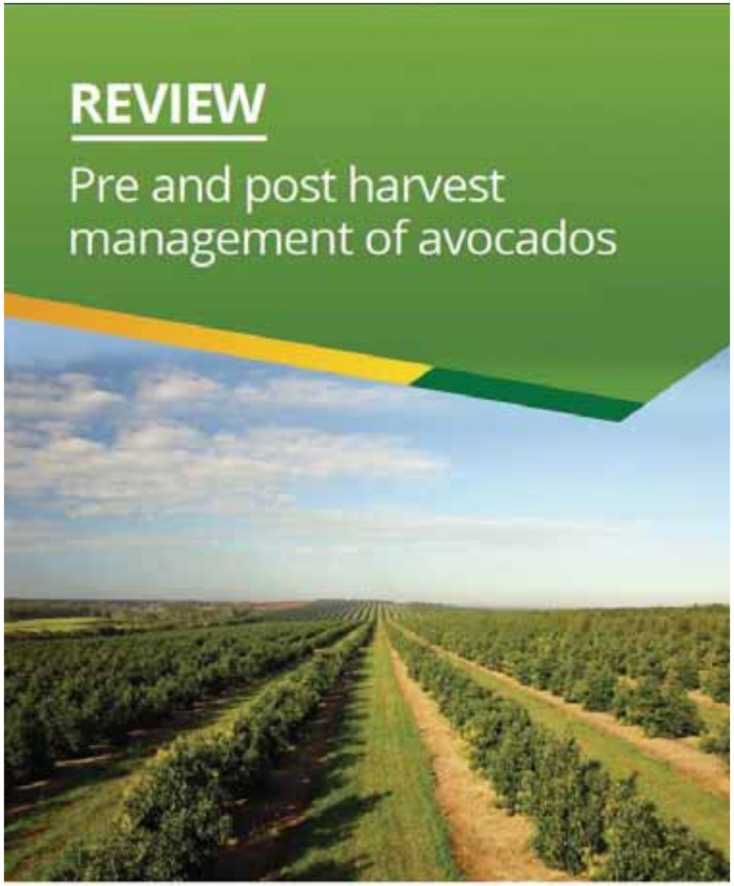
- If fruit pulp is **<20ºC,** keep shaded and pack within 48 hours of receival
- If fruit pulp is **20-30ºC** *either* pack within 24 hours *OR* room cool to below 15°C and pack within 3 days of receival
- If fruit pulp is **>30ºC** forced air cool below 15°C and pack within 3 days of receival

Keep fruit shaded

Apply fungicide within 24 hours of harvest *especially if fruit have been picked wet*

Control fruit during bin tipping

4. Review of research



3 Harvest

3.1 When to harvest

Weather and water

Key finding

It is widely recommended that fruit should not be picked while wet. Wet harvest can increase skin marking due to lenticel damage, postharvest rots and internal disorders. Continual rain can reduce the impact on disease – as microbes may be washed off the plant surfaces – but the other types of damage may still occur. Fruit that is turgid due to rain or recent irrigation is also likely to suffer increased lenticel damage, leading to skin spotting and development of dark patches on the fruit skin. Harvesting fruit when hot increases moisture loss even if bins are shaded, so may also affect end quality of fruit.

- It is widely recommended that avocados are not picked while wet, regardless of whether moisture is due to rain or even just dew. Fruit picked wet are more likely to develop stem-end rots, body rots and vascular browning[66].
- As little as 5mm rain in the 24 hours prior to harvest can increase postharvest rots (Figure 6). However, if rain continues for 48 hours or more, then the effect on rots is less, and may even revert to that observed in dry fruit. It seems possible that continual rain washes fungal spores off the trees, reducing the probability of infection during harvest[67].

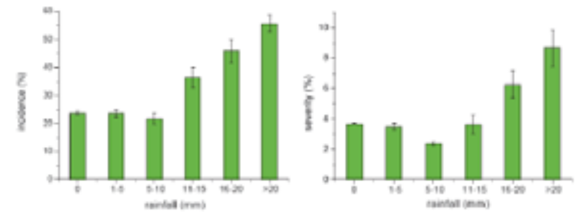


Figure 6. Impact of rain in the 24 hours prior to harvest on the incidence of stem-end rot (left) and the severity of body rots (right). From Pak et al., 2003.

- Both rain and irrigation increase turgidity of the fruit, swelling the lenticels in the fruit skin. Such fruit are more likely to suffer lenticel damage during harvest and normal handling, resulting in spotting and, sometimes, browning of the underlying tissue[67]. Damaged areas are prone to secondary rots, which can develop during cold storage[68].

[66] Duvenhage JA. 1993. The influence of wet picking on post harvest diseases and disorders of avocado fruit. SAAGA Yearbook 16:77-79.
[67] Pak HA et al. 2003. Impact of rainfall prior to harvest on ripe fruit quality of Hass avocados in New Zealand. NZ AGA Ann. Res. Rep. 3:22-
[68] Everett KR et al. 2008. Avocado lenticel damage: the cause and effect on fruit quality. Postharvest Biol. Technol. 48:383-390.

Training and roll-out of resources

- Revisit packhouses and review their cool chain study report
- Discuss new best practice resources and recommendations
- Pre-season training sessions with wider industry (growers, packers, transporters, wholesalers)

Specific items for discussion

- Suite of resources – suitable for industry needs?
- Feedback on Best Practice Guide and Problem Solver
  - Flexible recommendations based on situation? E.g. cool fruit sooner after harvest if weather is warmer

Cool Chain Best Practice Adoption (AV15010)

PRG Meeting – 14 March 2018

Objectives and Approach

1. Increase adoption of best practice
2. Reduce the incidence of quality defects
3. Increase awareness of factors that predispose fruit to quality defects

Review
- Postharvest research
- Best practice resources

Completed

Initial industry consultation

Refresh resources
- Best practice guide
- Problem solver
- Checklists

Completed

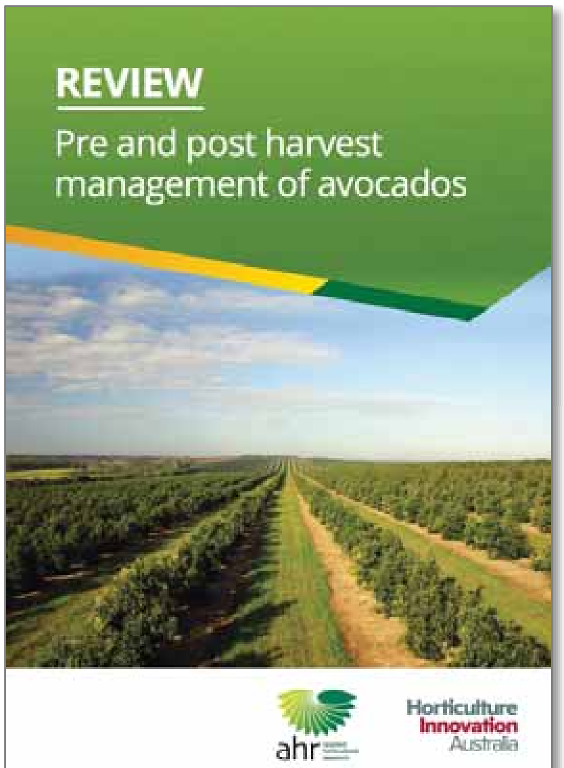
Packhouse studies
- Identify issues
- Best practice recommendations

Underway

Rollout
- Regional workshops
- Revisit packhouses

Reviews

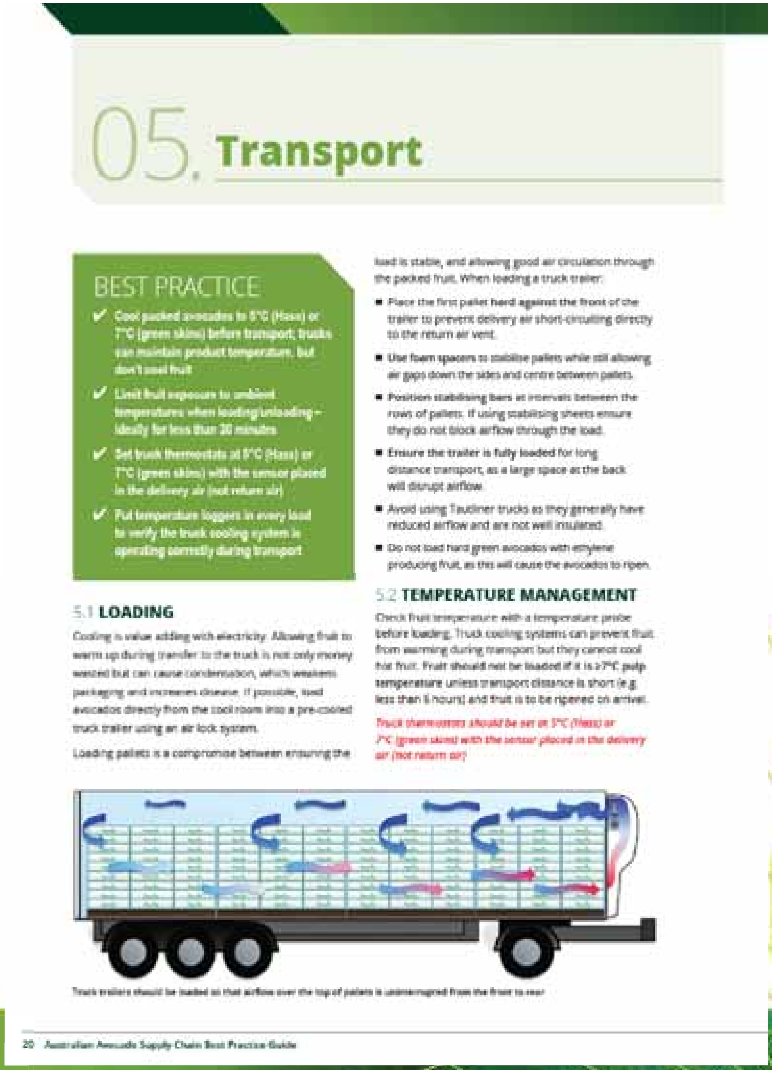
Review of pre- and postharvest management



Review of current resources

Resources – Best Practice Guide

- Includes:
  - Pre-harvest
  - Harvesting
  - Packhouse
  - Transport
  - Ripener/Wholesaler
  - Distribution Centre
- Detailed, for office use



05. Transport

BEST PRACTICE

✔ Cool packed avocados to 5°C (Hass) or 7°C (green skins) before transport; trucks can maintain product temperature, but don't cool fruit

✔ Limit fruit exposure to ambient temperatures when loading/unloading – ideally for less than 20 minutes

✔ Set truck thermostats at 5°C (Hass) or 7°C (green skins) with the sensor placed in the delivery air (not return air)

✔ Put temperature loggers in every load to verify the truck cooling system is operating correctly during transport

5.1 LOADING

Cooling is value adding with electricity. Allowing fruit to warm up during transfer to the truck is not only money wasted but can cause condensation, which weakens packaging and increases disease. If possible, load avocados directly from the cool room into a pre-cooled truck trailer using an air lock system.

Loading pallets is a compromise between ensuring the load is stable, and allowing good air circulation through the packed fruit. When loading a truck trailer:

- Place the first pallet **hard against the front** of the trailer to prevent delivery air short-circuiting directly to the return air vent.
- **Use foam spacers** to stabilise pallets while still allowing air gaps down the sides and centre between pallets.
- **Position stabilising bars** at intervals between the rows of pallets. If using stabilising sheets ensure they do not block airflow through the load.
- **Ensure the trailer is fully loaded** for long distance transport, as a large space at the back will disrupt airflow.
- Avoid using Tautliner trucks as they generally have reduced airflow and are not well insulated.
- Do not load hard green avocados with ethylene producing fruit, as this will cause the avocados to ripen.

5.2 TEMPERATURE MANAGEMENT

Check fruit temperature with a temperature probe **before loading**. Truck cooling systems can prevent fruit from warming during transport but they cannot cool hot fruit. **Fruit should not be loaded if it is ≥7°C pulp temperature** unless transport distance is short (e.g. less than 6 hours) and fruit is to be ripened on arrival.

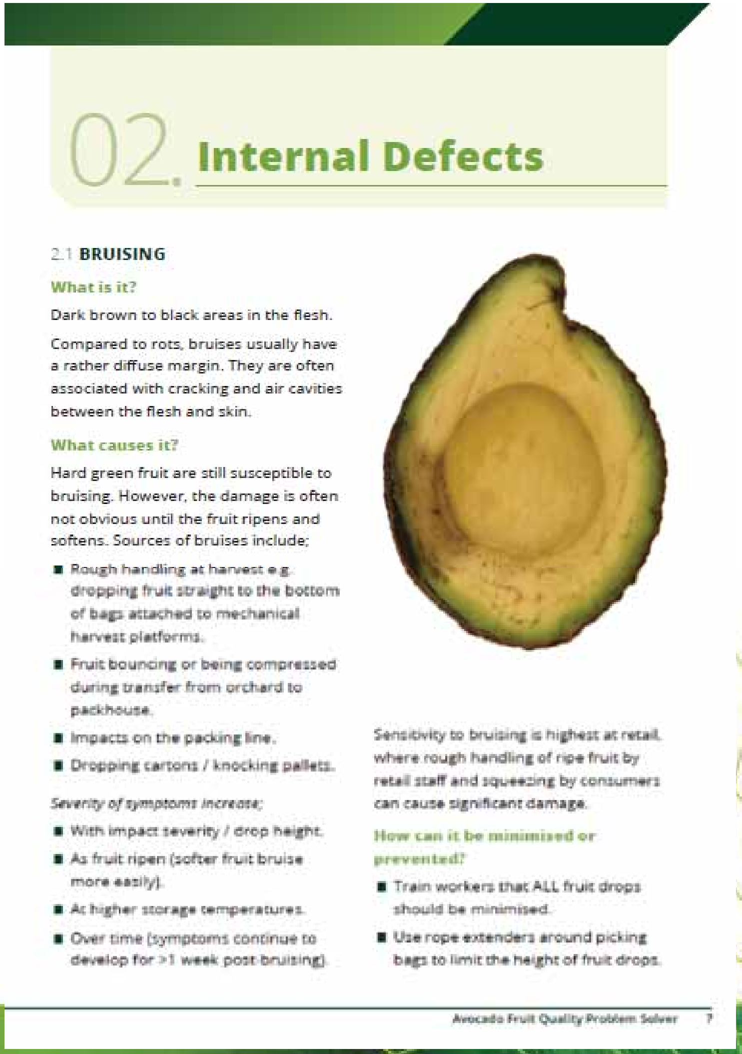
Truck thermostats should be set at 5°C (Hass) or 7°C (green skins) with the sensor placed in the delivery air (not return air)

Truck trailers should be loaded so that airflow over the top of pallets is uninterrupted from the front to rear

20 Australian Avocado Supply Chain Best Practice Guide

Resources – Problem Solver

- Details:
  - What is it?
  - What causes it?
  - How can it be minimised or prevented?
- Includes:
  - Internal defects
  - External defects
  - Ripening and storage
- Day-to-day use


02. Internal Defects

2.1 BRUISING

What is it?

Dark brown to black areas in the flesh.

Compared to rots, bruises usually have a rather diffuse margin. They are often associated with cracking and air cavities between the flesh and skin.

What causes it?

Hard green fruit are still susceptible to bruising. However, the damage is often not obvious until the fruit ripens and softens. Sources of bruises include;

- Rough handling at harvest e.g. dropping fruit straight to the bottom of bags attached to mechanical harvest platforms.
- Fruit bouncing or being compressed during transfer from orchard to packhouse.
- Impacts on the packing line.
- Dropping cartons / knocking pallets.

Severity of symptoms increase;

- With impact severity / drop height.
- As fruit ripen (softer fruit bruise more easily).
- At higher storage temperatures.
- Over time (symptoms continue to develop for >1 week post-bruising).

Sensitivity to bruising is highest at retail, where rough handling of ripe fruit by retail staff and squeezing by consumers can cause significant damage.

How can it be minimised or prevented?

- Train workers that ALL fruit drops should be minimised.
- Use rope extenders around picking bags to limit the height of fruit drops.

Avocado Fruit Quality Problem Solver 7

Resources – Checklists

- Outlines key actions needed to maintain postharvest quality
  - Content from Best Practice Guide and Joyce et al.
- Includes
  - Good management practices
  - Useful records
  - Priority (fill-in)
  - Status (fill-in)
- Day-to-day use by relevant staff

Resources – plenty of input

- Other project teams– AV15011 (Retail), AV15009 (Bruising)
- QDAF – Lindy Coates, Peter Hoffman, Simon Newett
- PRG members
- Costa's technical team
- Hort Innovation

Resources – next steps

- Will be added to AAL online BPR
- Printed and distributed
- Launch:
  - Roadshow
  - Talking Avocados
  - Media release
  - Hort Innovation Comms
  - Hort Connections

Packhouse and supply chain studies

Region	Number of packhouses	Date (2017)
North Qld	3	May
Central Qld	3	July to August
NSW North coast	2	September
Riverland SA	1	October
Southwest WA	3	November

Measured

- Temperature from harvest through the supply chain
- Impacts and skin damage on packing-lines
- Quality after ripening and retail

Confidential reports for each packhouse

- Identified:
  - Issues
  - Improvements
- Range of issues:
  - Poor **temp management after harvest, especially transport**
  - Harvest impacts with mechanical work platforms
  - Skin damage on packing lines
  - Impacts on packing line

2. Packing line impacts

Some of the key impact areas on the packing line were identified and noted, as follows;

Bin tip onto the feed-belt

Drop to elevator

Drop from washer to Sportek

Drop-point door

The Techmark impact recorder was run down the packing line in appropriate sections (x 3). After an initial run through the whole line, potentially problematic areas were identified and the ball re-run focusing on specific drops.

Time stamped data was recorded in terms of both maximum G-force and velocity change. Data was graphed according to the MaxG recorded at each impact point.

Extension roll out

- Follow up initial work with major packhouses to implement the new best practices resources:
  - Build on **issues identified in packhouse studies**
  - **Showcase the new resources** and train staff
  - Conduct grower and adviser **workshops in each region**
  - **Conduct a webinar** and record for those unable to attend

Workshop dates

- *Manjimup* – **17 April**
- *Crows Nest and Sunshine Coast* – **1 & 2 May**
- *Waikerie or Renmark* – **21 May**
- *Atherton Tablelands* – **31 May**
- *Stuarts Point* – **5 June**
- *Childers* – **7 June**

Alongside

- AAL update
- HARPS (TBC)
- PASE Export project (TBC)

For discussion

- Extension roll out
  - What results do you think growers/packers/transporters will be most interested in?
  - Can we make this interactive? E.g. fill in checklist
- Keeping best practice materials within Australian Industry?
- Where to from here?

Avocado supply chain quality improvement (AV15010)

Project objectives

Objectives

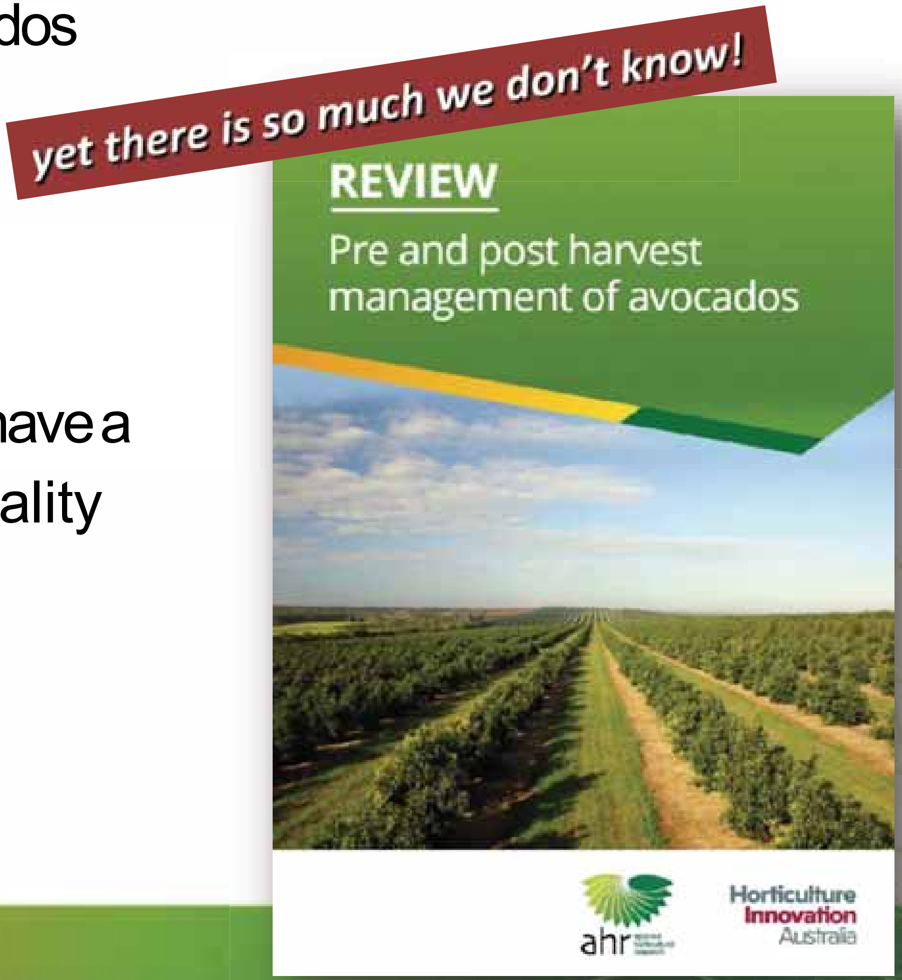
1. Increase the adoption of best practice in cool chain management and postharvest handling across all sectors of Australian avocado supply chains from orchard to retail
2. Reduce the incidence of body rots and other quality defects in avocado fruit (25% → 10%)
3. Increase the awareness across the supply chain of factors that predispose fruit to quality defects

Key supply chain issues

- ***Rots, bruises and other internal issues***
  - Handling from harvest to retail
  - Pre-harvest fungicide management eg applications during flowering
  - Postharvest fungicides – are they effective?
  - Cooling after harvest and packing
  - Temperature management throughout the cool chain – keeping cool, but not too cool?
  - Fruit age

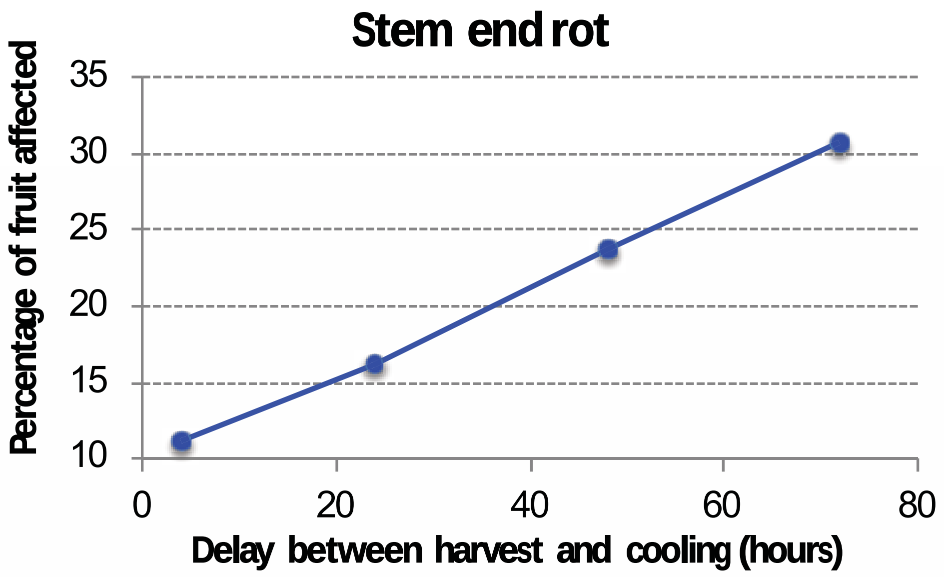
Pre- and postharvest review

- Much has been written about pre- and postharvest management of avocados
  - 8,750 papers on CAB
  - 150,000 results on Google Scholar
- Completed a 70 page review
- Both pre- and postharvest factors have a significant effect on postharvest quality



Pre-cooling

- Avocados don't ripen on the tree because of the "***tree factor***"
  - The tree factor degradation affected by temperature + time
- ***Variable temperature → variable ripeness at retail***



Fruit that stays warm after harvest is more likely to develop rots and internal discolouration, lose weight, ripen faster

Cooling and storage

- ***Warm fruit loses moisture. Fast cooling after packing is essential*.**

Product can deteriorate as much in 1 hour at 25°C
as in 1 week at 1°C

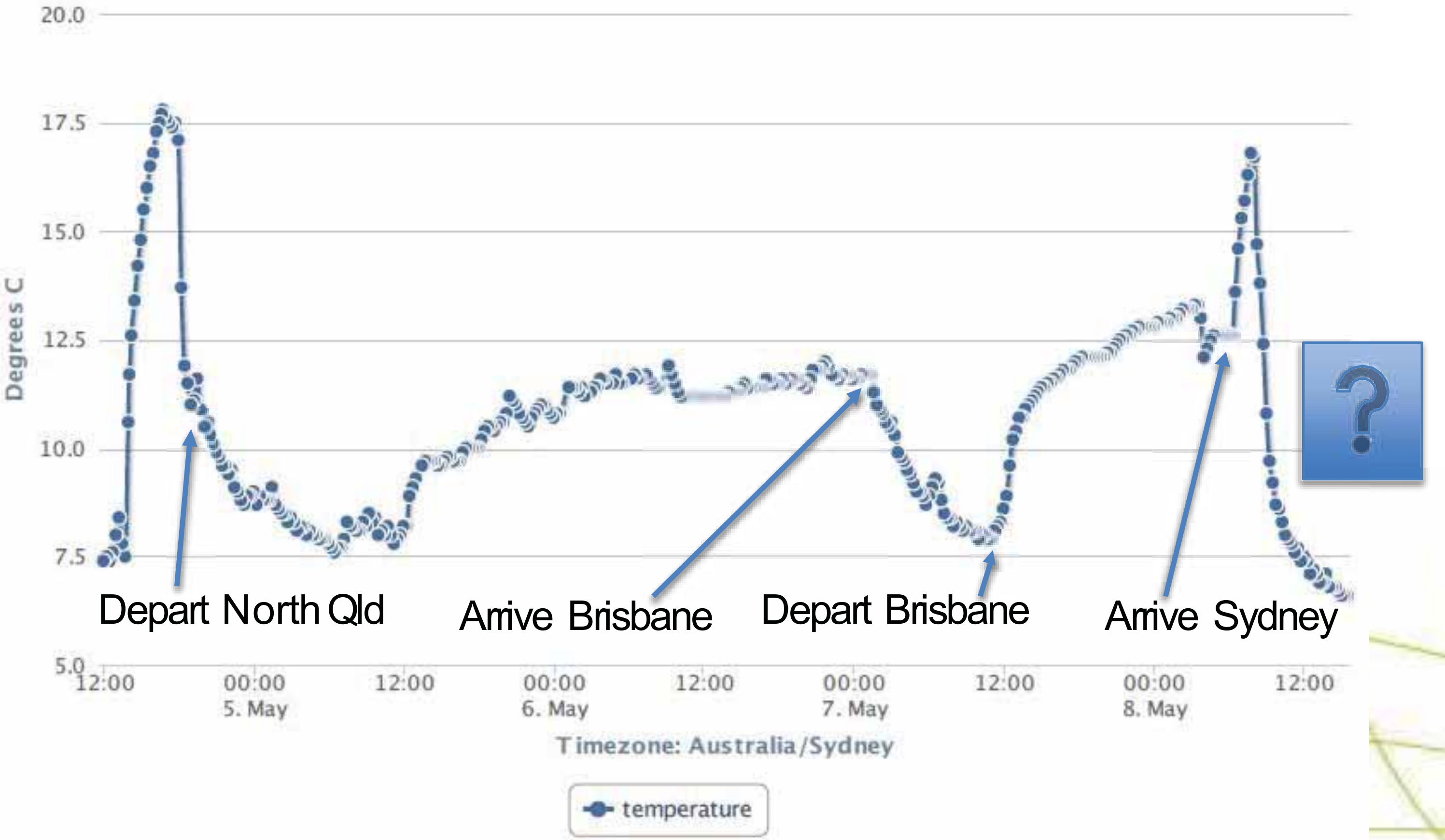
- ***Delays in cooling allow fruit to start ripening.***
  - Increased chilling sensitivity
  - Increased rots
  - Variable ripeness at retail

Cooling and transport

Breaks in the cold chain can have a major impact on quality

Break of only 5 hours can increase rots

The longer that fruit has been stored, the bigger the effect of a break



Fruit age

- **Fruit should not be more than 30 days old when ripe (in a good cool chain)**
  - Anti-fungal compounds in fruit decline during storage
  - Stem end rots advance during storage
  - After 4 weeks incidence and severity of rots markedly increases

Potential trial

- Supply chain monitoring from orchard to retail
  - Temperature
  - Time
- Feedback to growers, transporters, wholesaler/ripener, retailer

Produce Marketing AUSTRALIA

ahr applied horticultural research

Hort Innovation

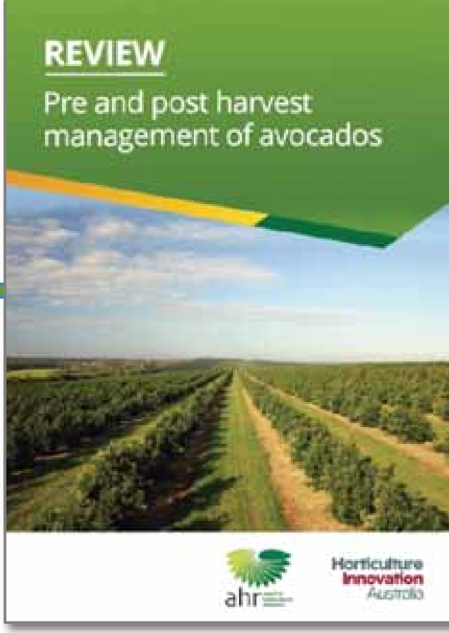
Avocado supply chain quality improvement (AV15010)

Objectives and Approach

1. Increase adoption of best practice
2. Reduce the incidence of quality defects
3. Increase awareness of factors that predispose fruit to quality defects

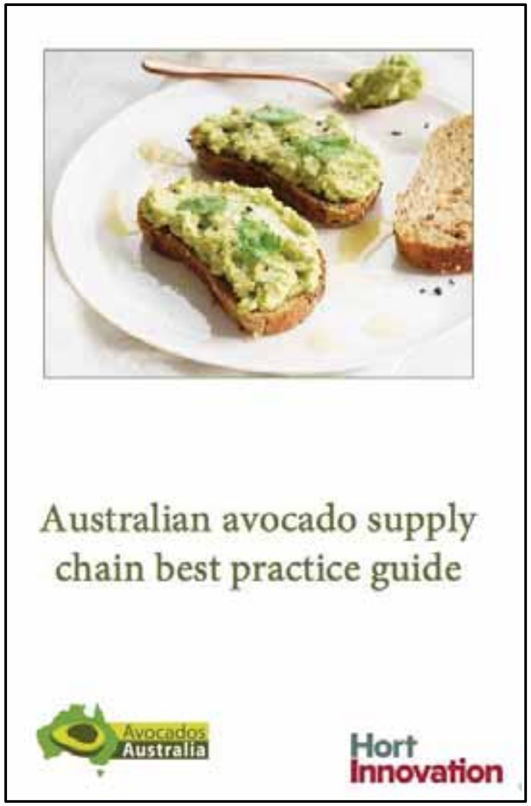
Reviews and Resources

Review of pre- and postharvest management

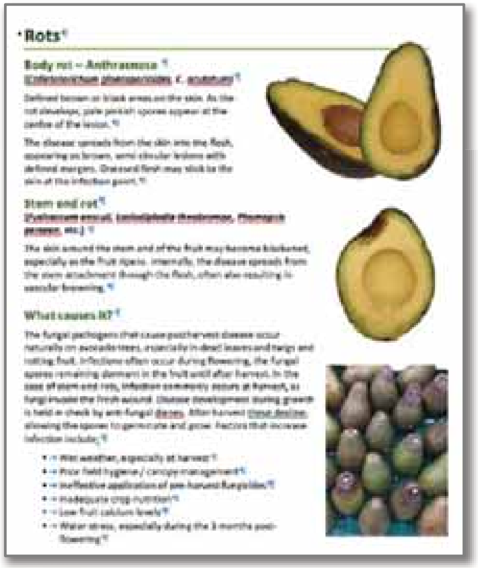


Review of current resources

Best Practice guide



Problem Solver



Checklist

Packhouse and supply chain studies

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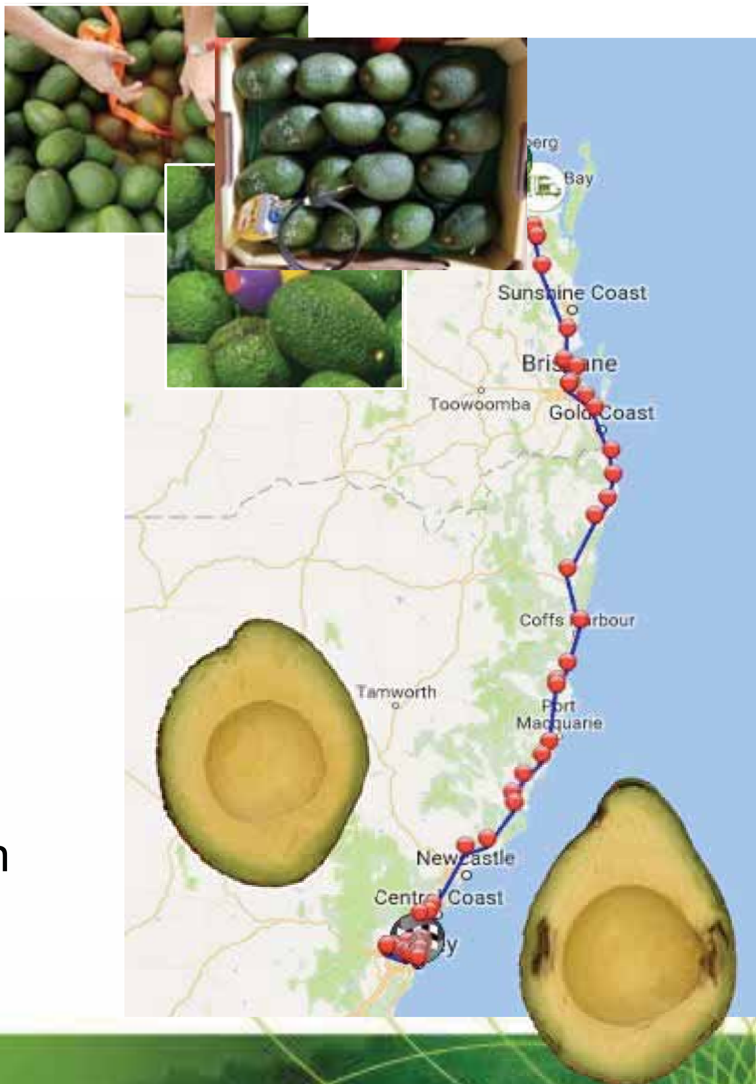
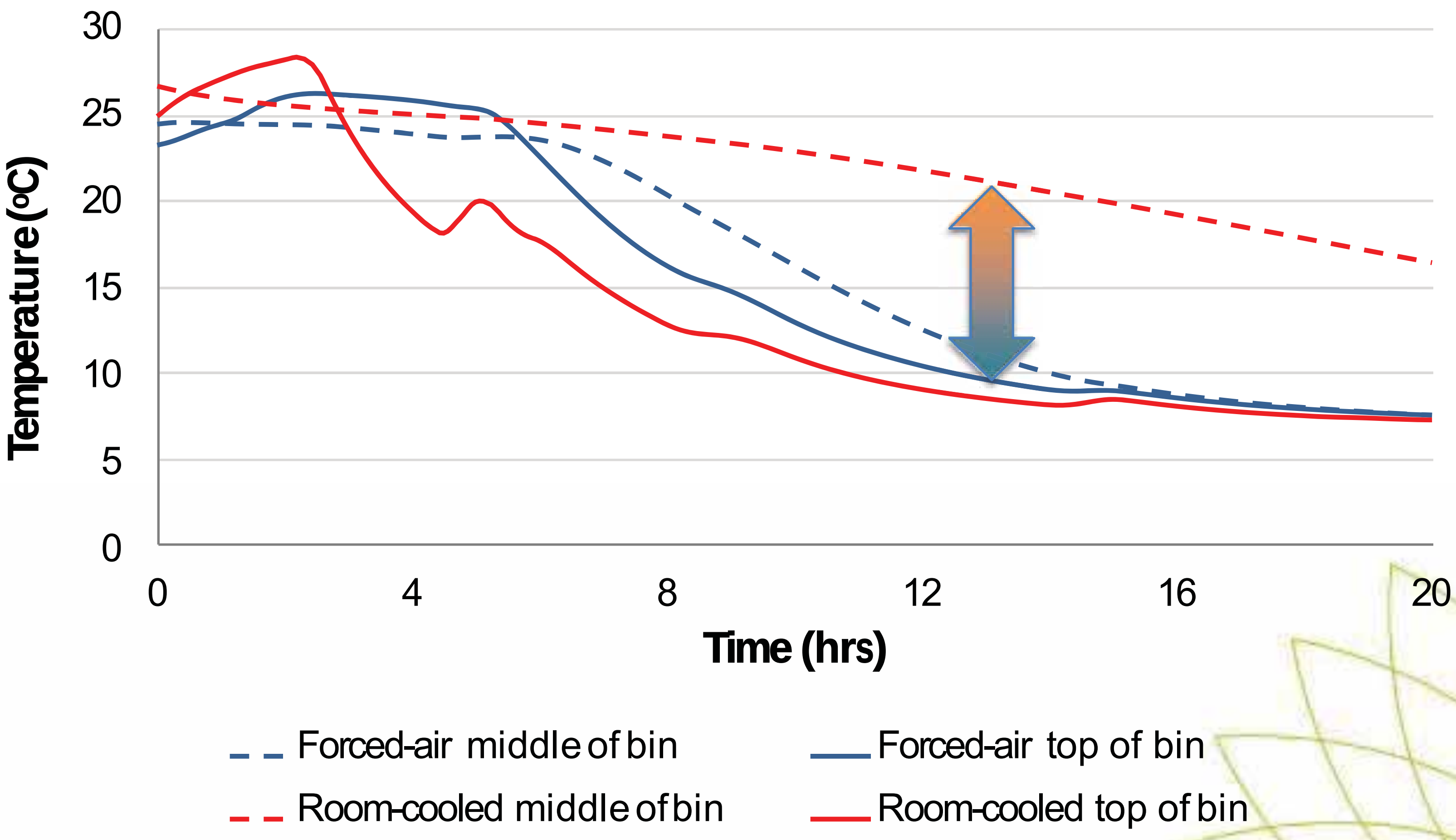


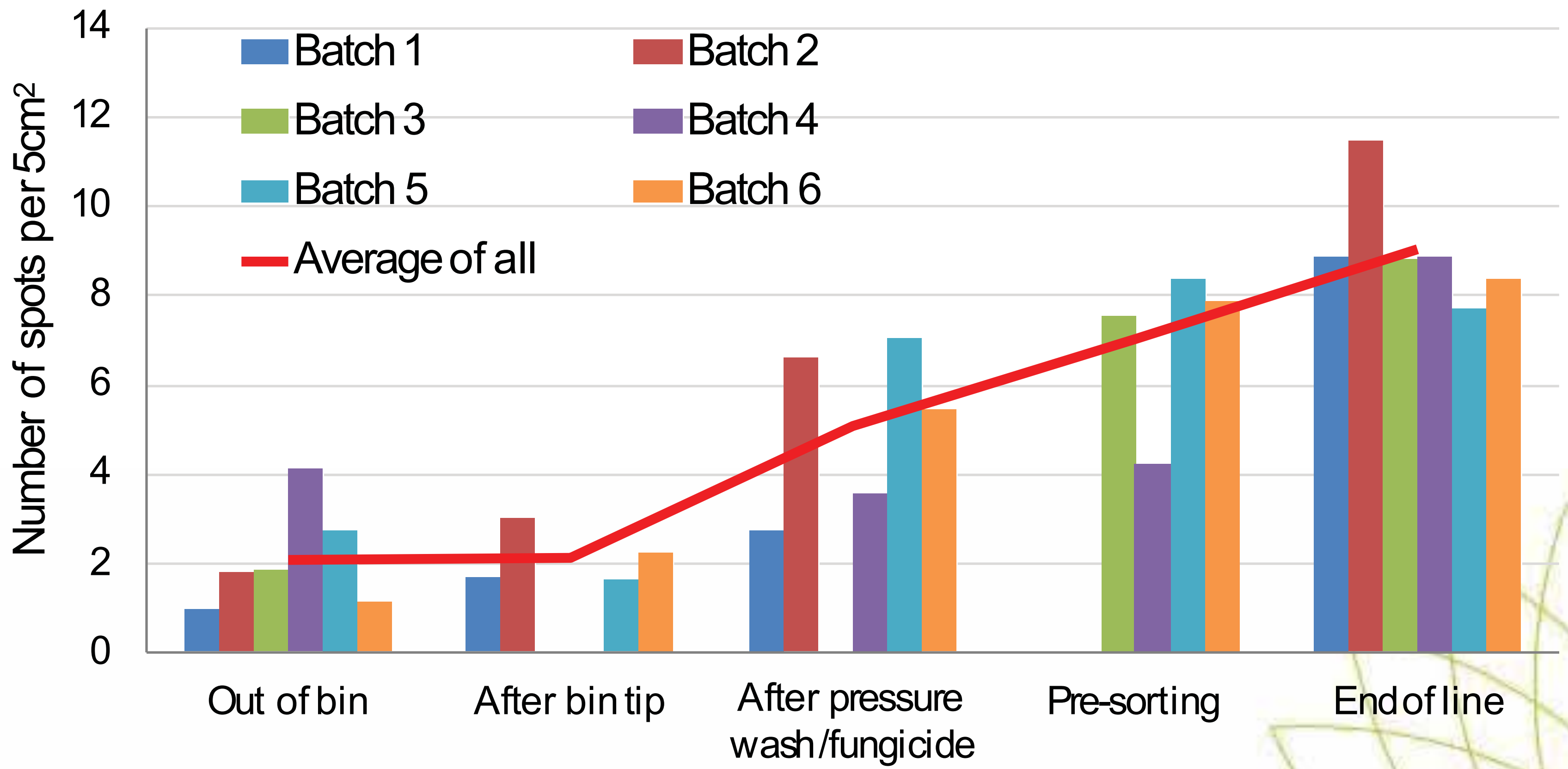
Measured

- Temperature from harvest through the supply chain
- Impacts and skin damage on packing-lines
- Quality after ripening and retail

Bin cooling


30
25
20
15
10
5
0
Temperature (ºC)
0
4
8
12
16
20
Time (hrs)
Forced-air middle of bin
Forced-air top of bin
Room-cooled middle of bin
Room-cooled top of bin

Damage on the packing line



Transport temperatures

25 Departs

	Packhouse A	Packhouse B
Fruit with internal damage at packing	5%	1%
Average temperature during transport	**9.2°C**	**14.5°C**
Temperatures during ripening	17–18°C *Average 17.9°C*	12–20°C *Average 16.9°C*
Fruit with internal damage at dispatch from ripener	5%	**25%**
Fruit with internal damage at retail	0%	**30%**

Key Quality Issues

Variable fruit ripeness **doubles fruit squeezing** at retail and reduces retail sales by at least **30%.**

- ***Bruising and fruit rots***
  - Poor temperature management, ***especially during transport***
  - Rough handling on packing lines
- ***Variability in ripeness***
  - Poor temperature management after harvest
  - Dry matter variability?
- **What do Mission Produce do?** *(22% global production!)*
  - Hydrocool on arrival to 7-10°C, then cool store at 5-7°C
  - Packing facility at 7°C
  - Minimise drops, optical sorting, air blade drying, re-cool

Extension roll out

- Follow up initial work with major packhouses to implement the new best practices resources:
  - Build on **issues identified in packhouse studies**
  - **Showcase the new resources** and train staff
  - Conduct grower and adviser **workshops in each region**
  - **Use a multi-faceted extension approach**: workshops, printed and electronic resources, webinars, video, industry champions

R&D gaps and ideas

Grower/adviser focused extension program to drive practice change

(Similar to Soil Wealth/ICP in the vegetable industry)

- Engage growers and advisers, packhouse operators with best practice information.
- Use a mix of demonstration sites, electronic and social media, masterclasses, workshops, E-Learning. Link to AAL via website.

Cooling methods and delays

- Effects on fruit quality of different cooling delays and cooling methods
- Costs and benefits of different cooling systems

Supply chain monitoring with GPS

- Temperature monitoring program using new low cost GPS loggers

R&D gaps and ideas

In-field NIR for harvest efficiency

- Map orchards by harvest maturity.

Postharvest disease management

- Link risk (disease load, weather) to decision to pluck or clip
- Effect of fungicide applications during flowering
- Effect of delays in fungicide application after harvest
- Fruit surface coatings and waxes for anthracnose management

Ground truthing in WA

- Most research in Queensland – does this apply the same in WA?
- Different nutrition? Different pathogens? High harvest temperatures?

applied horticultural research

Improving avocado quality

Jenny Ekman

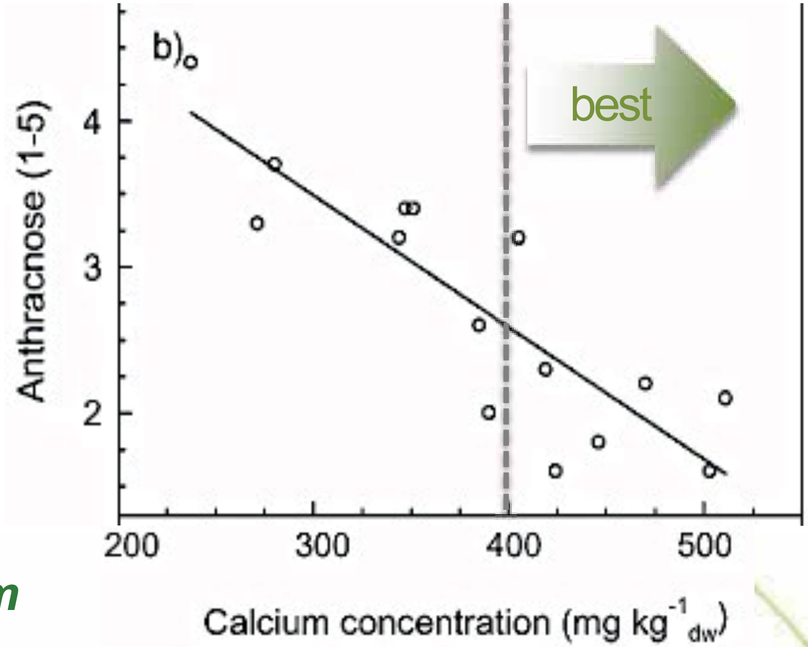
This talk

- Up to **25%** of avocados have a defect at retail
  - Bruising
  - Rots
  - Vascular browning
  - Internal discolouration

- Poor handling by retail staff and squeezing by consumers contribute to bruising
- BUT internal issues, rots and discolouration are also major issues.. and relate to the whole supply chain…

Pre-harvest: Nutrition

- High calcium in fruit
  - Reduces disease
  - Reduces disorders
- BUT there is no reliable way to ***increase calcium in fruit***
- Excess nitrogen
  - Increases disorders and ***reduces calcium***

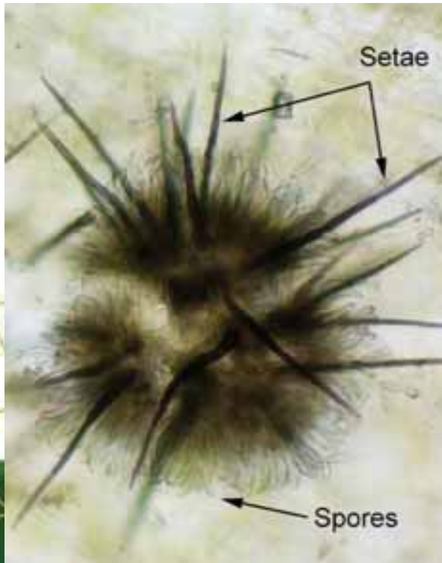


From Hofman et al, 2002

MEASURING: Calcium is highest in mature fruits from indeterminate shoots, at the stem end and on the sunny side of fruit

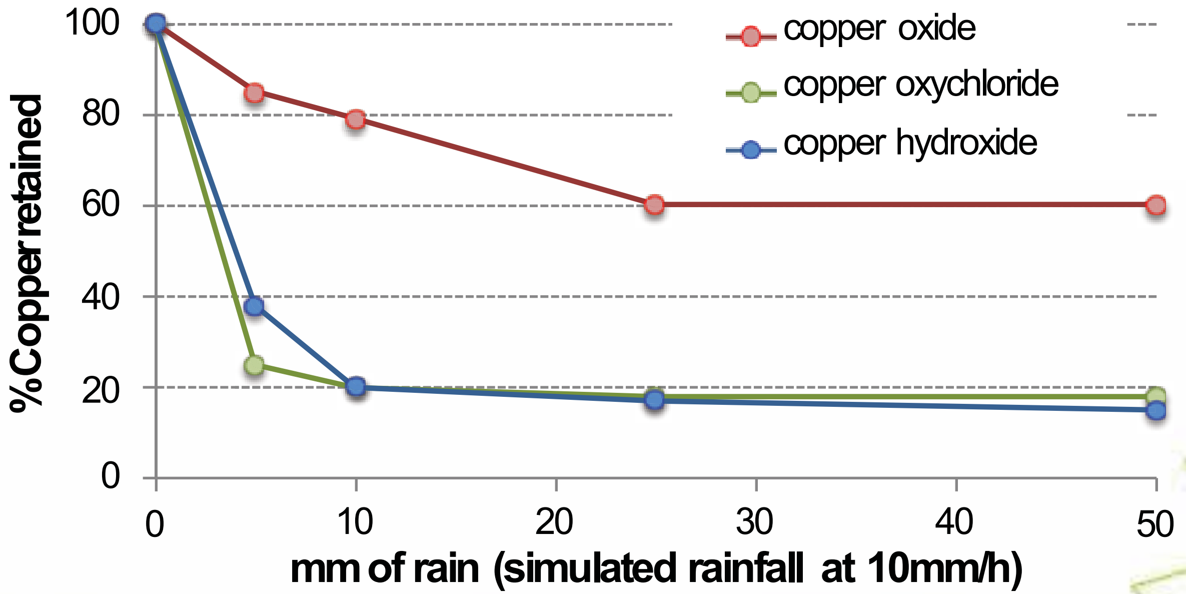
Pre-harvest: Fungicides

- Disease resistance due to ***anti-fungal dienes*** in fruit
  - Increased by plant cytokinins, SARs (phosphorus acid)
  - Disappear over time (~25 days)
- Application of fungicides ***at flowering*** is critical
  - Suppress spore germination and spread into young fruitlets
- Hygiene and pest management limit disease spread



Pre-harvest: Fungicides

- Continued sprays through fruit development prevent inoculum building up in the orchard.
  - Strobilurins (Amistar, Flint) alternated with copper sprays 1:2
  - Red copper oxide has best adhesion in rainy weather



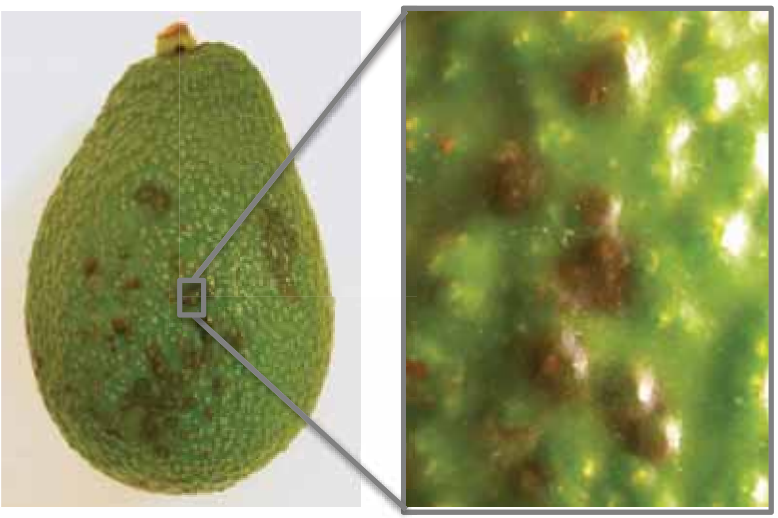
Centrilab, Holland

Harvest

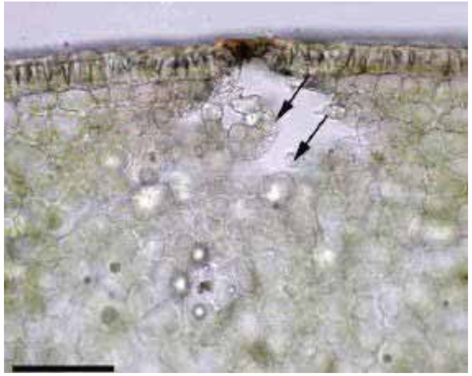
- Fruit should not be picked wet

Rain / irrigation / condensation = swollen lenticels = peel damage = rots

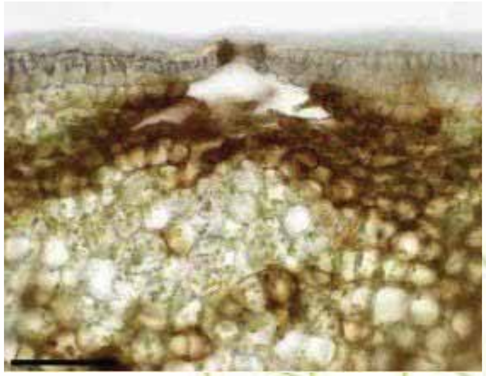
From Pak et al, 2003
Everett et al, 2008



Peel damage



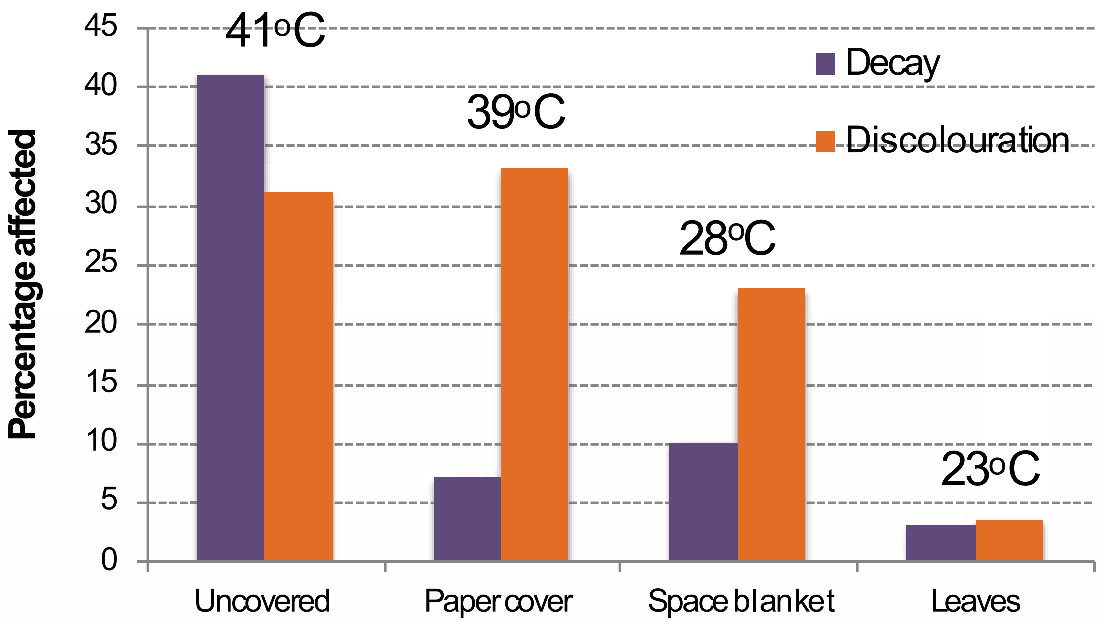
Normal lenticel



Damaged lenticel

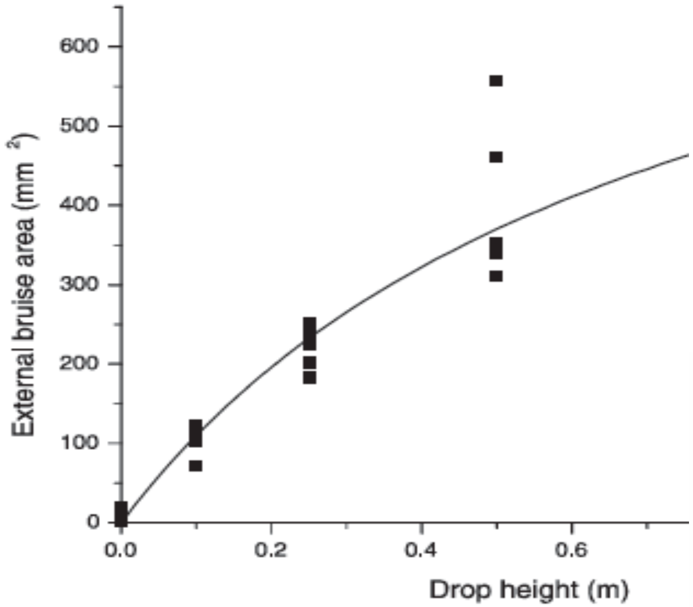
Harvest

- Fruit can be much hotter (~10°C) than the surrounding air



Bruising: farm and packhouse

- Hard avocados are susceptible to bruising

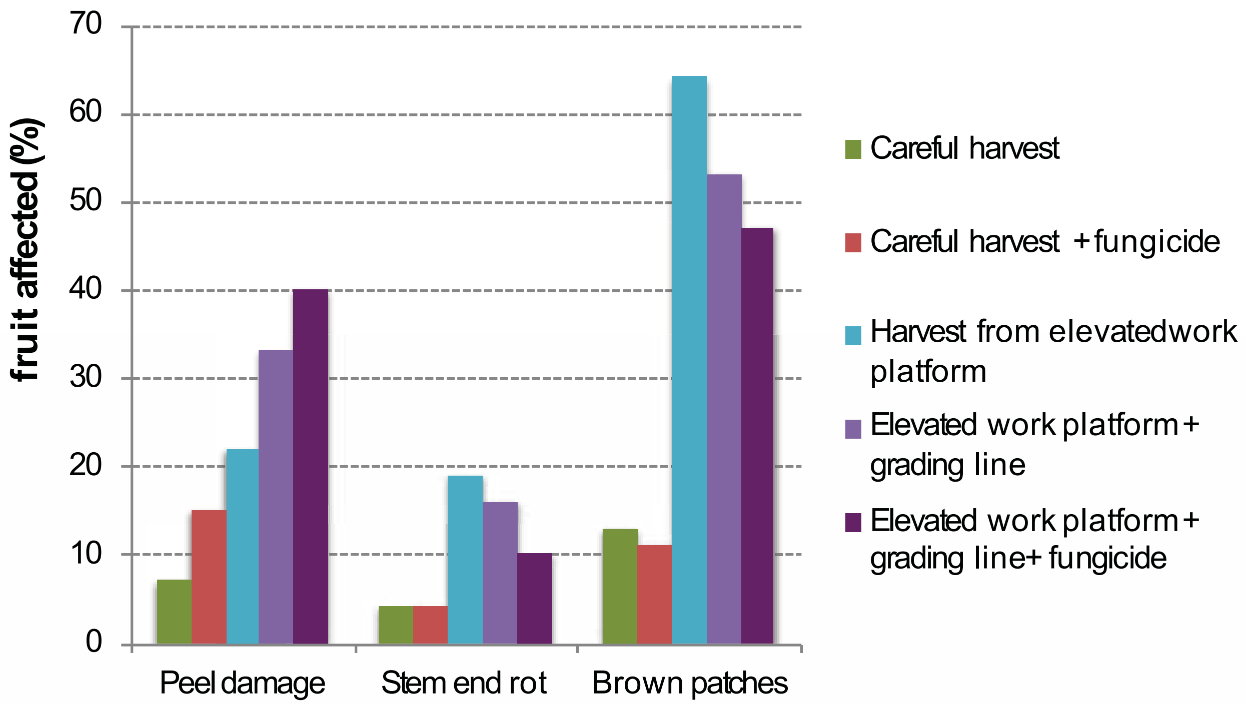


From Mandemaker et al, 2006.

ALL fruit drops should be minimised

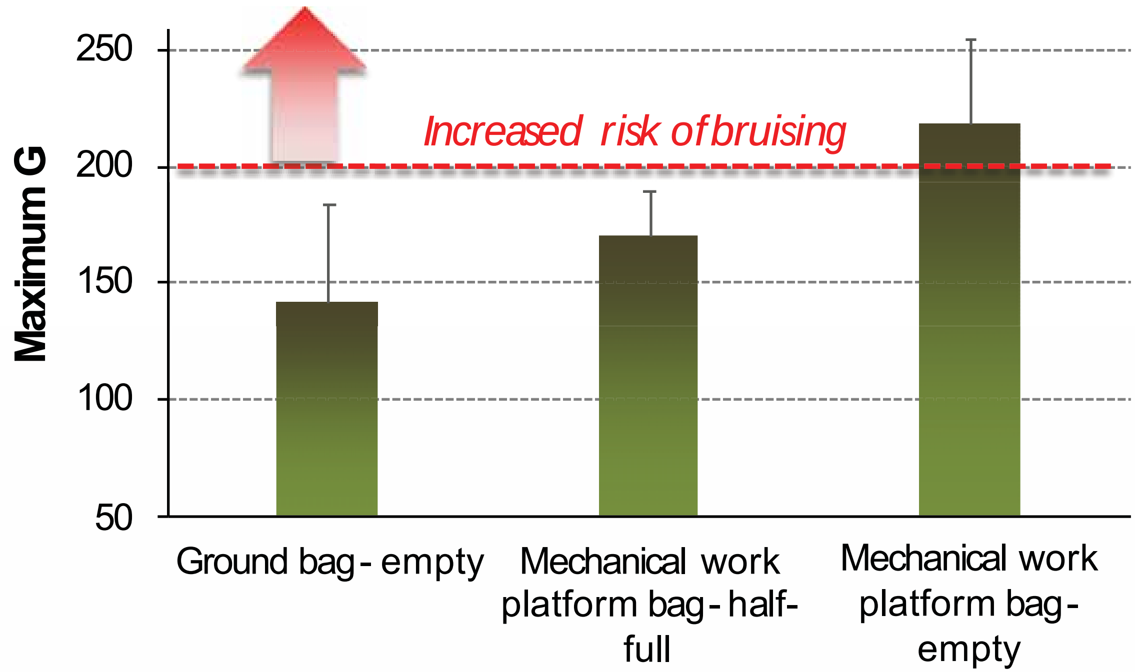
Bruising: farm and packhouse

- Elevated work platforms (cherry pickers) are commonly used but can cause other issues



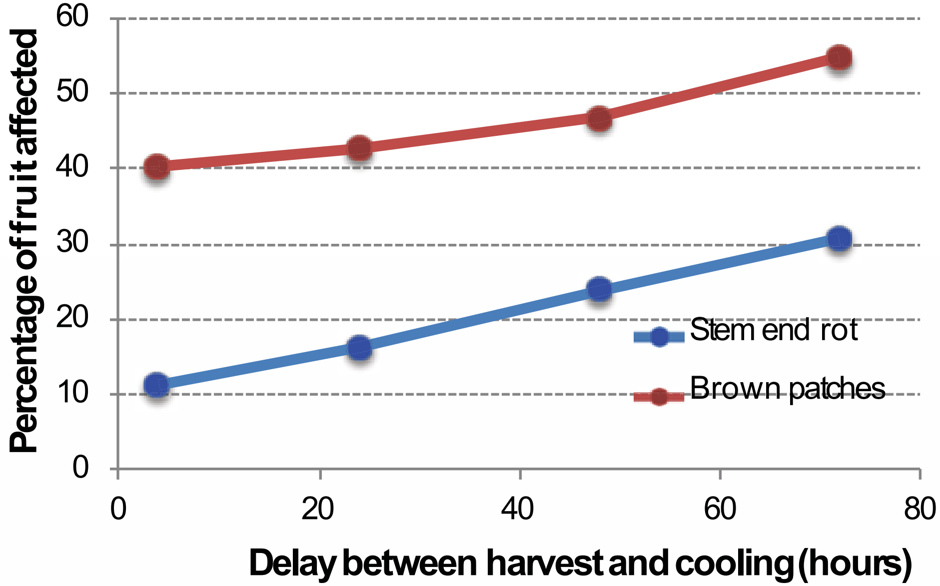
Bruising: farm and packhouse

- Significant impacts can occur during picking



Pre-cooling

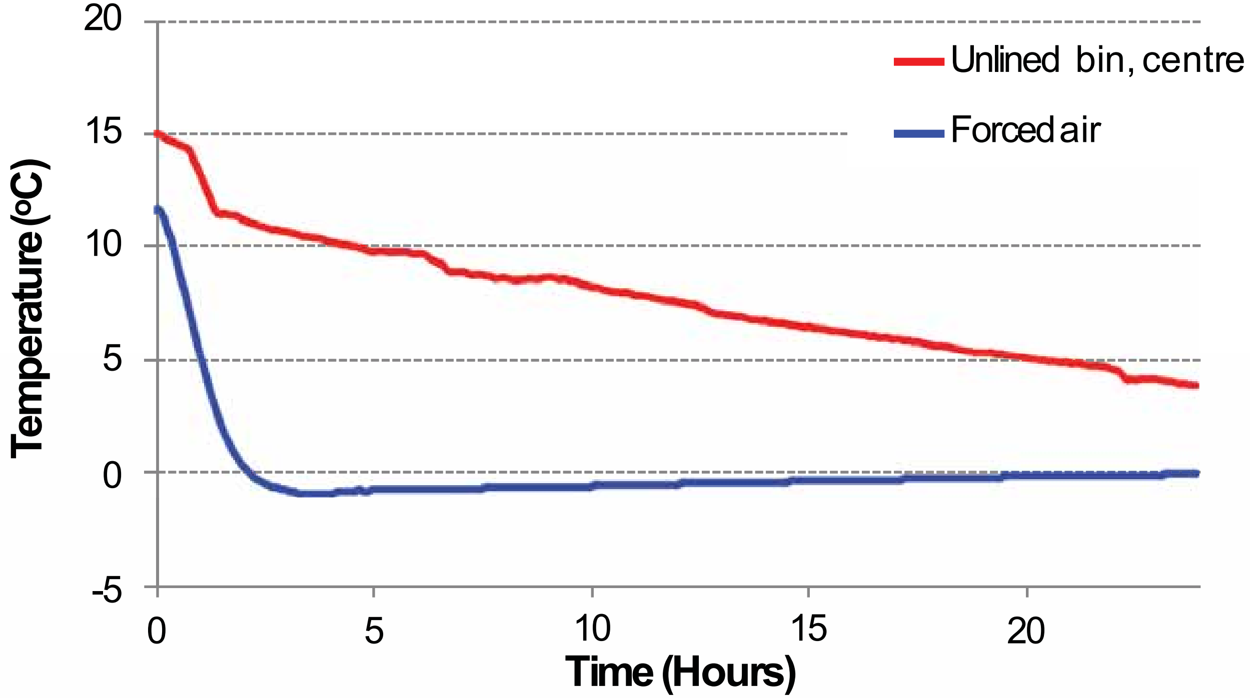
- Avocados don't ripen on the tree because of the "***tree factor***"
  - Degradation of the tree factor depends on temperature + time



Fruit that stays warm after harvest is more likely to develop rots and internal discolouration, lose weight, ripen faster

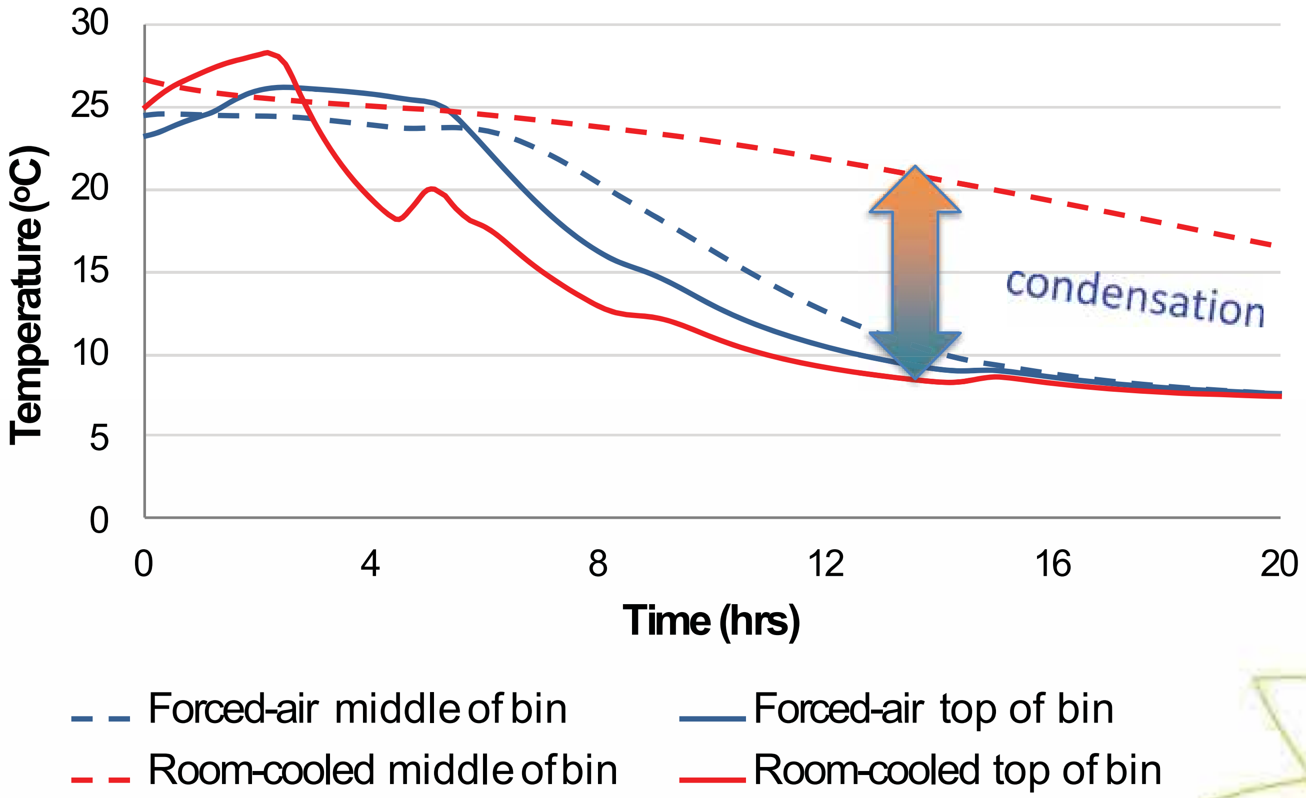
Temperature variability in bins

How warm are avocados in the centre of bins?



Temperature variability in bins

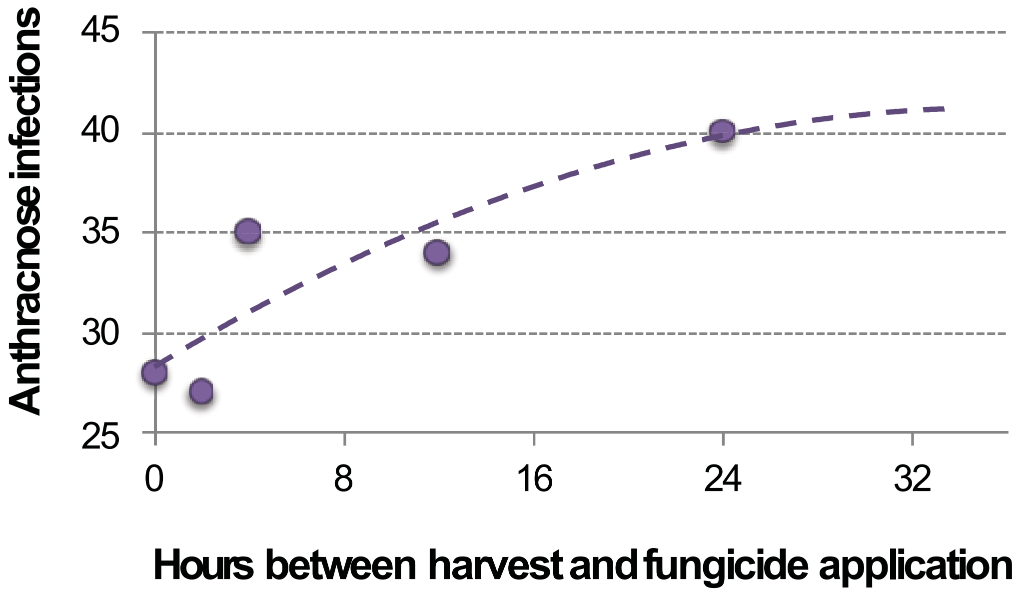
Temperature variability → increased variability in ripeness



Worse if the cold room is overloaded

Postharvest fungicides

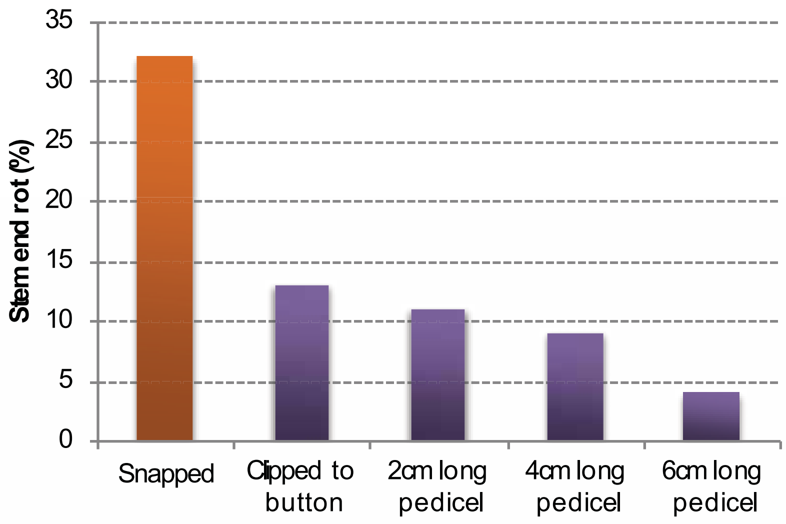
- ***Postharvest fungicides <u>can</u> reduce rots by 20 to 50%***
  - Timing likely to be critical for infections at harvest eg SER
  - Less effect on pre-harvest infections
  - Results with SARs (systemic acquired resistance) so far disappointing
  - Thyme oil?

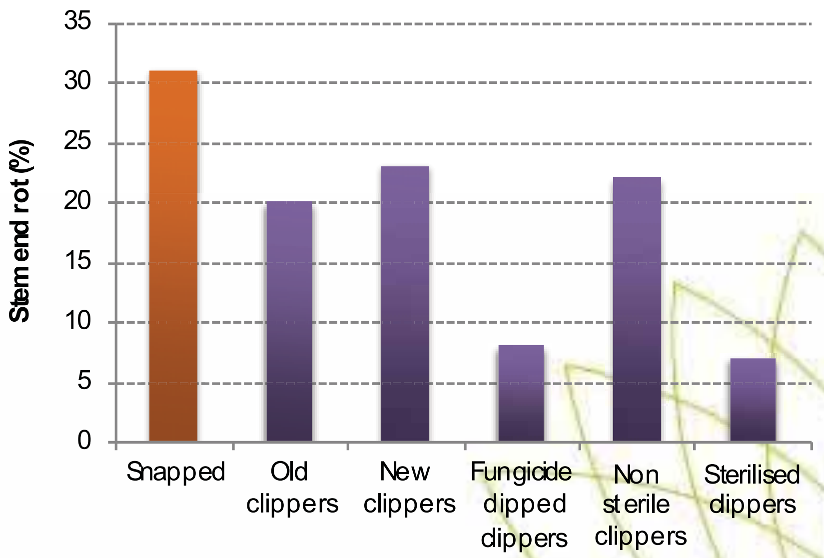


Derived from Everett, 2012

Pluck or Clip?

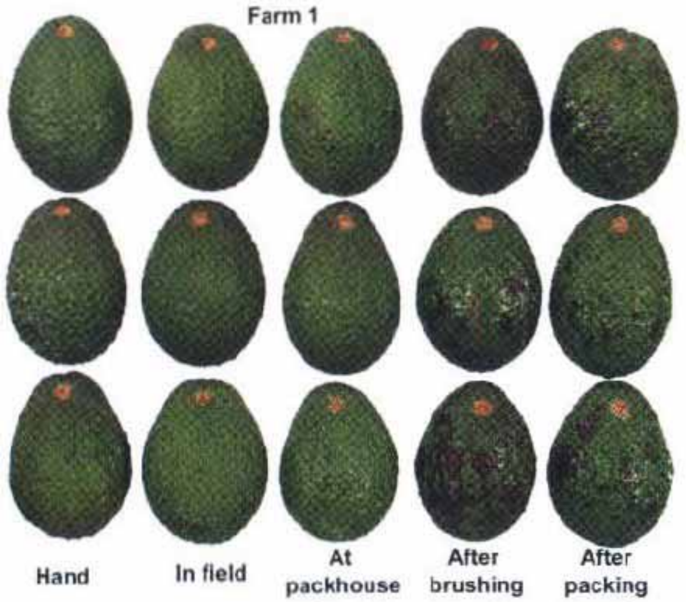
- In Australia Hass are plucked, other varieties are normally clipped
  - Clipping reduces disease
  - Snapping takes half the time!

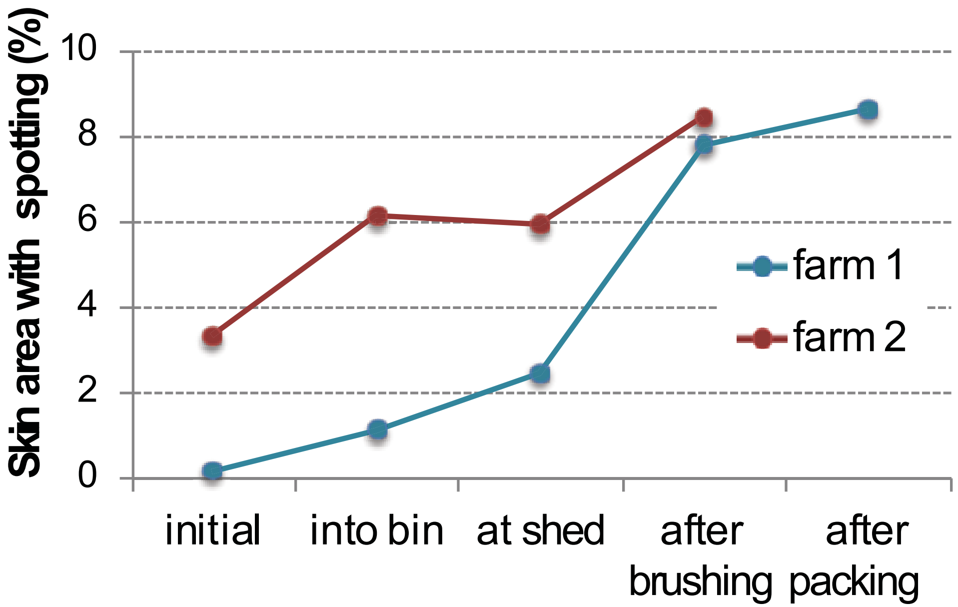




Grading and packing

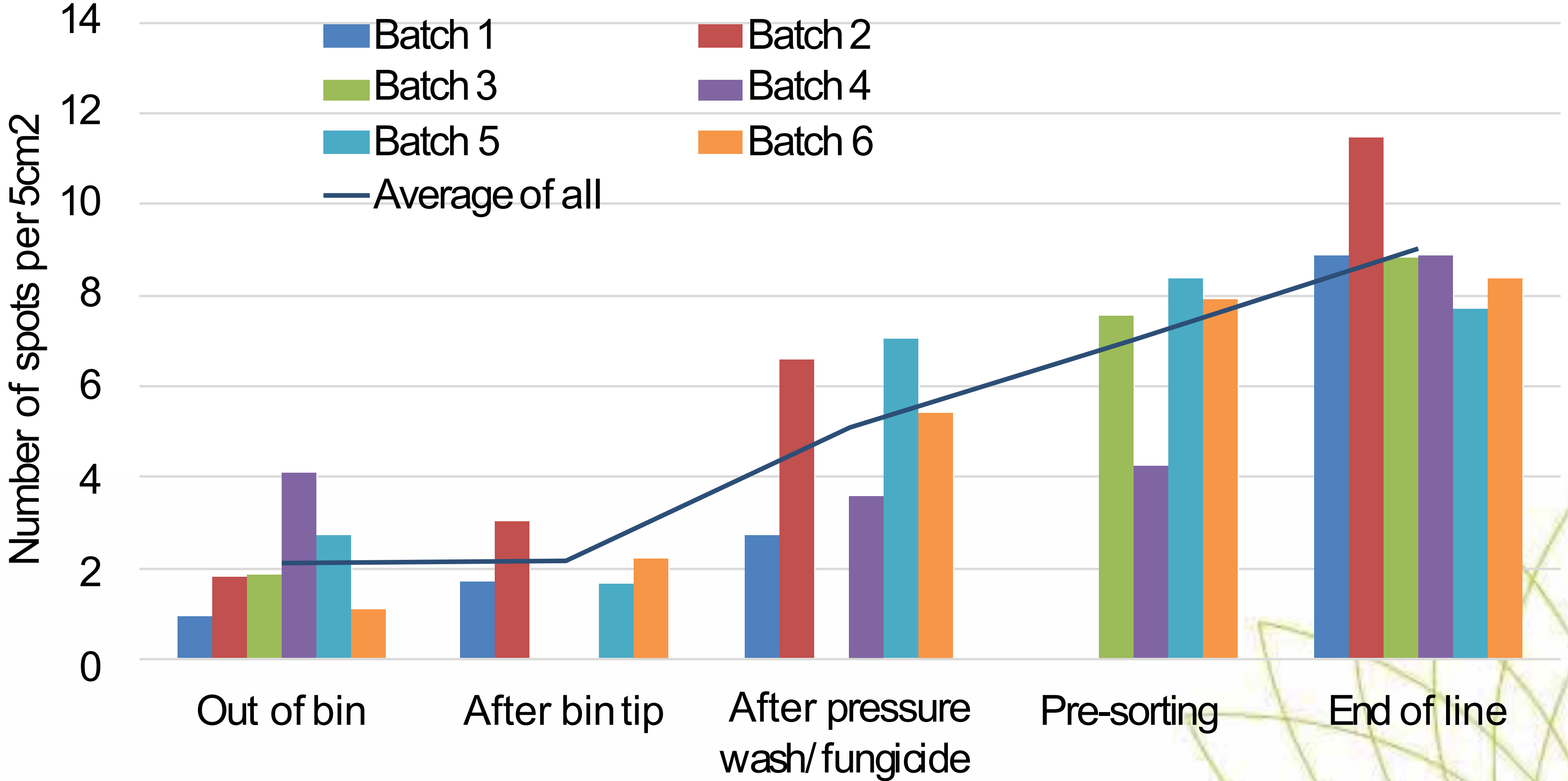
- Fruit may need washing, but should not be packed wet
- Brushes on packing lines can jostle fruit
  - Increase lenticel damage, spotting
- Dropped trays = bruised fruit
- Packing fruit while cold reduces bruising





Hofman, 2005

Lenticel damage on the packing line



Grading and packing

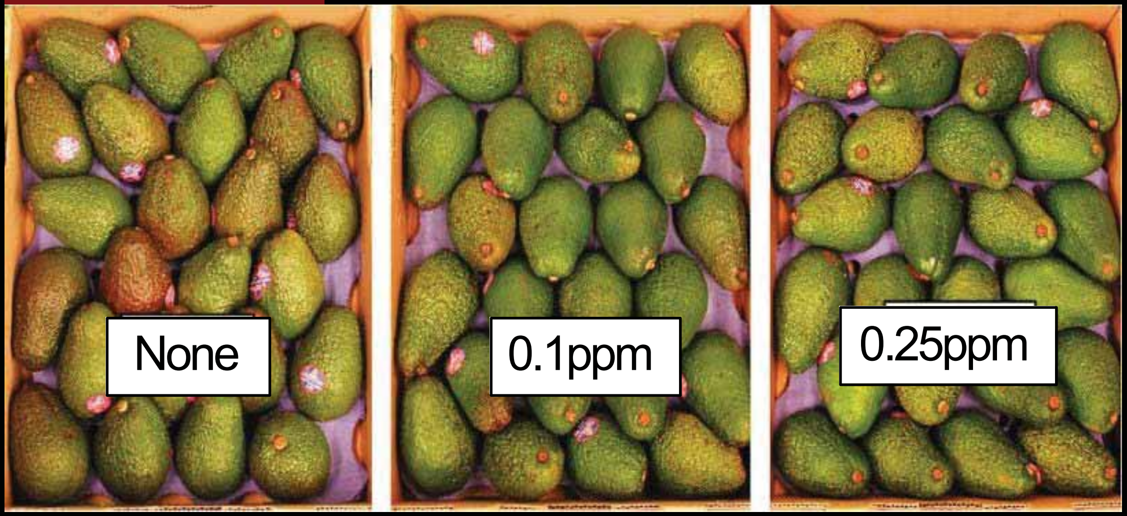
- ***Sorting using Near Infrared Spectroscopy (NIR)***
  - Segregate fruit based on dry matter → ***less variability in ripeness***
  - Detects bruising and internal rots → ***less defects at retail***
  - **In-line sorting could reduce variable ripening**

James Cook University

Smart Fresh (1-MCP)

- Delays ripening
- Extends low temperature storage (42d @5°C)
- Reduces chilling sensitivity
- Used by South Africa
- Variable ripening is the biggest issue

4 weeks



7 weeks

4 or 7 weeks at 5.5°C +1d @20°C. *From Woolf et al., 2005*

Cooling and storage

- ***Warm fruit loses moisture. Fast cooling after packing is essential***.

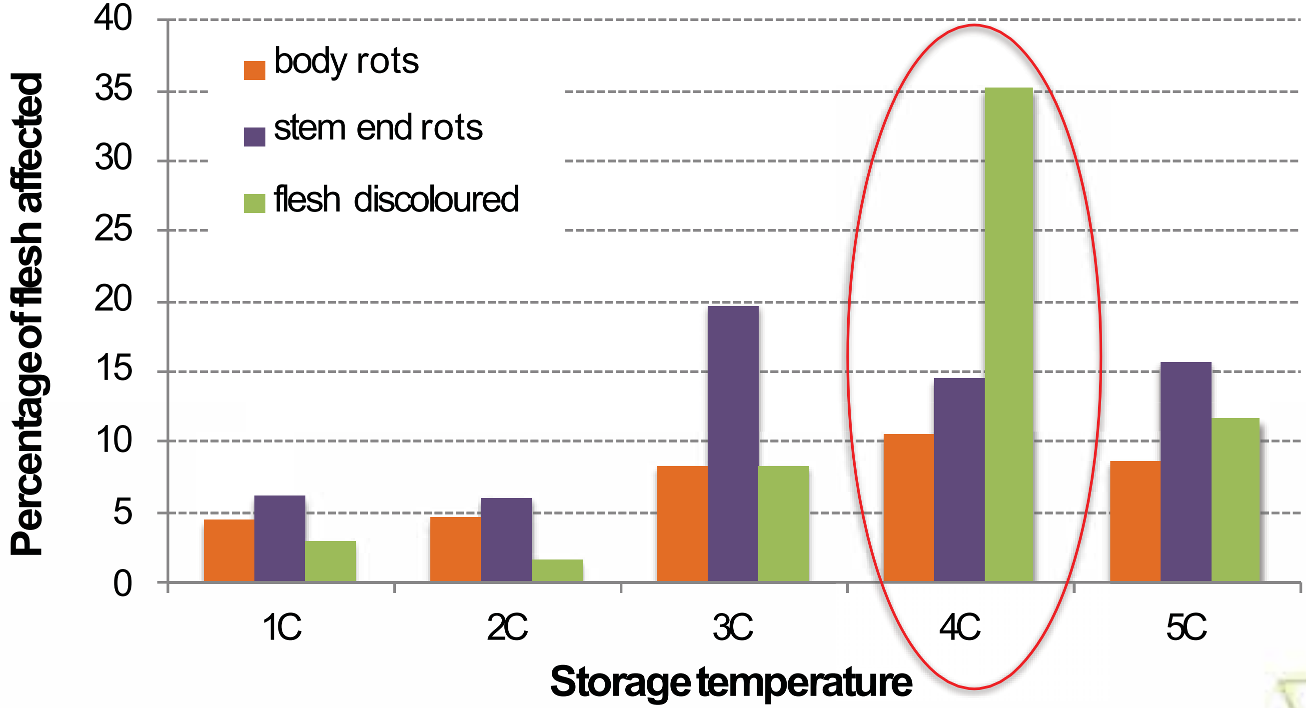
> *Product can deteriorate as much in 1 hour at 25°C*
>
> *as in 1 week at 1°C*

- ***Delays in cooling allow fruit to start ripening.***
  - Increased chilling sensitivity
  - Increased rots
  - Variable ripeness at retail
- ***Room cooling is very slow***, 0.5°C per hour
- ***Forced air cooling is 3 to 8 x faster***, min. 2°C per hour

Cooling and storage

- ***Concept of Killing Zone***

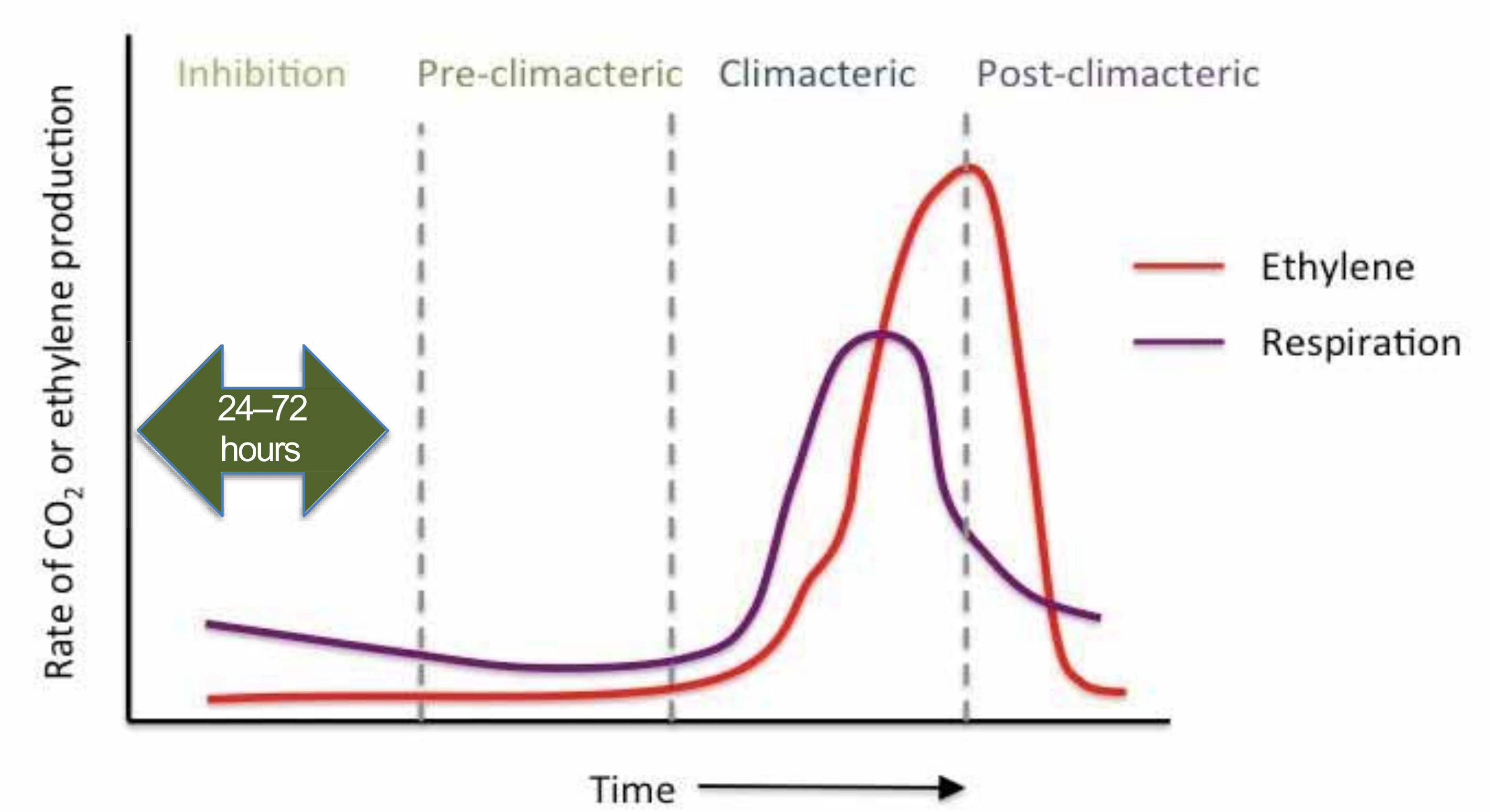
Derived from Hofman et al, 2010



Pre-conditioned at 6 °C for 3 days, then stored at 1 to 5 °C for 31 days, ripened at 20 °C

Ripening

Once ripening starts, it is unstoppable



Ripening

- ***Dry Matter*** content critical to ripening time
- ***High temperatures*** increase the rate of ripening but reduce quality
- ***Ripened fruit need to be held to allow for distribution and retail***
  - Rubbery: store at 2 °C
  - Soft: store at 5–8 °C

Rubbery-sprung

Sprung-softening

Softening-firm

Fruit quality after 7 days at 2 °C


Fresh Mushrooms
PLEASE KEEP COOL
STORE AT 2°C
AUSTRALIAN MUSHROOMS
FRESH MUSHROOMS
KEEP ME COOL
Now in Season
GROWN & PACKED BY
COUNT
14 20 25 32
16 22 28
18 23 30
CLASS 1
Locally Grown
VARIETY
Rootz
Wild Rocket
NET. WT. 1.5kg
Product of Australia

Key supply chain issues

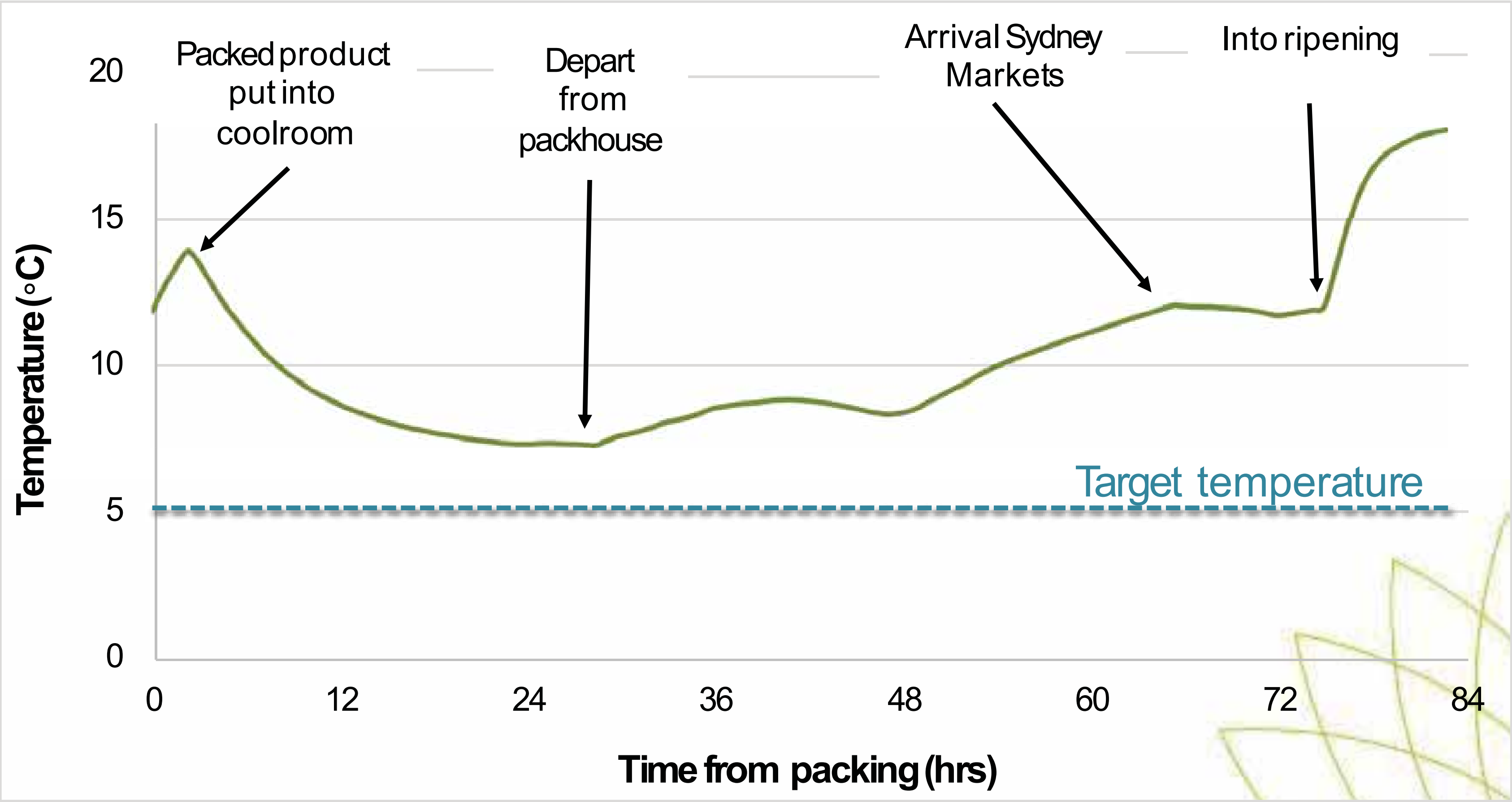
- ***Variability in ripeness***
  - **Temperature management** after harvest
  - **Dry matter** variability
  - **Ripener skills** – are CO_2 and ethylene monitored? Is temperature managed?

- ***Rots, bruises and other internal issues***
  - **Handling** from harvest to retail – avoiding ALL drops
  - **Pre-harvest fungicide** management eg applications during flowering
  - **Postharvest fungicides** – effectiveness if delayed?
  - **Cooling times and temperatures** from harvest through transport and storage
  - **Fruit age**

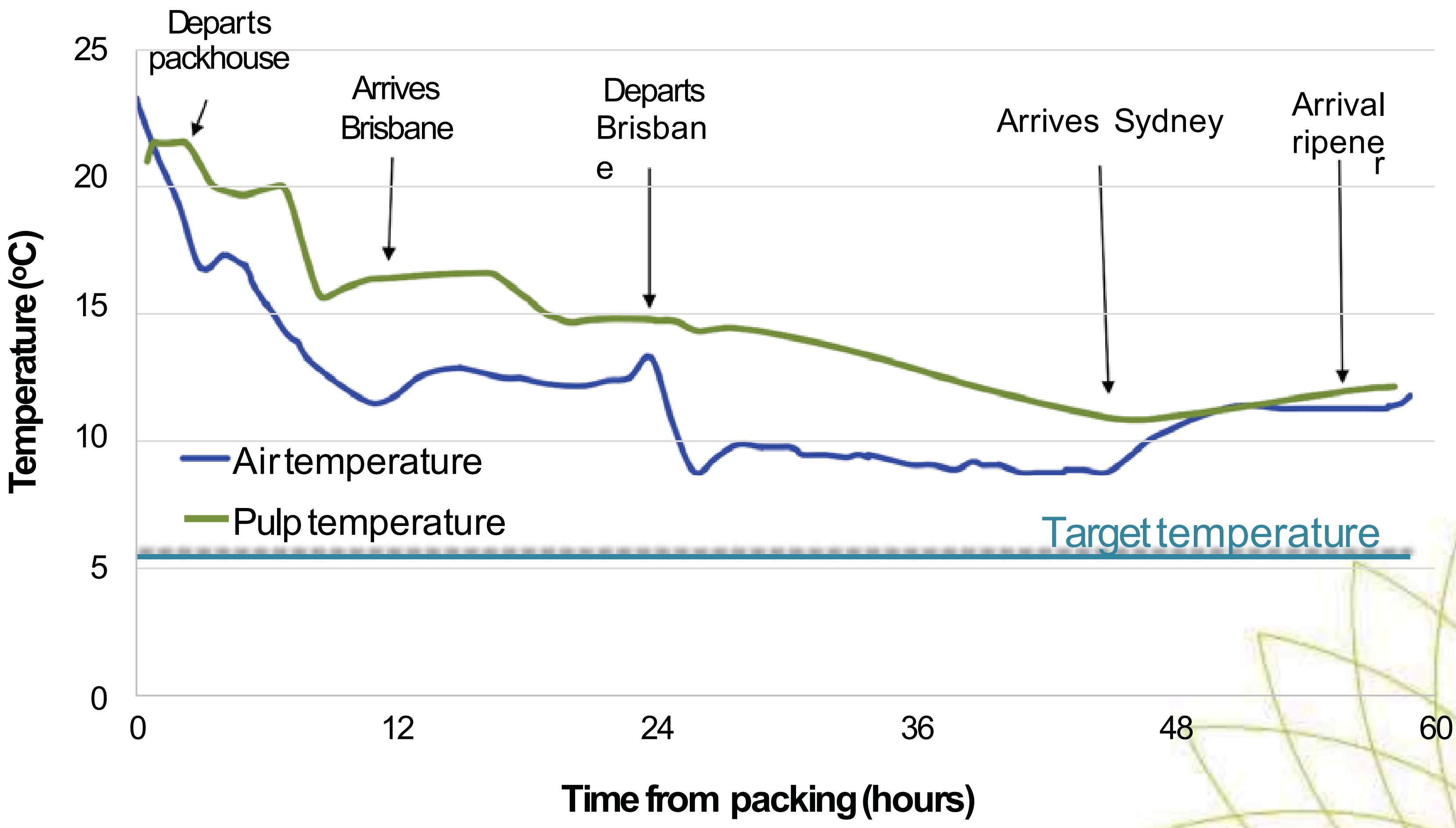
Cool chain studies: Central Qld

- Logging temperatures from harvest to retail
- Comparing quality at:
  - End of pack line
  - Dispatch from ripener
  - Retrieval from retail store

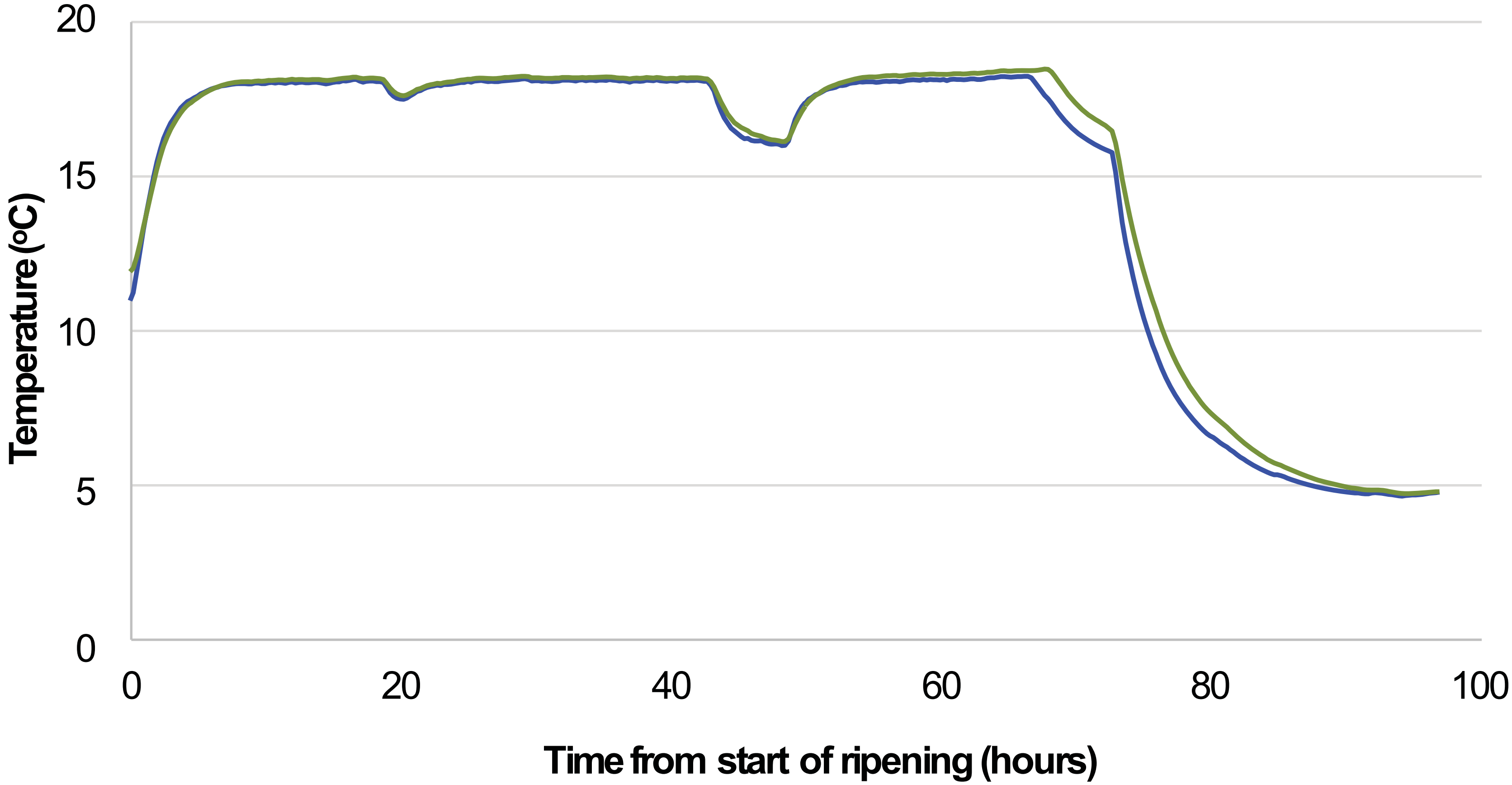
Packhouse A to ripener



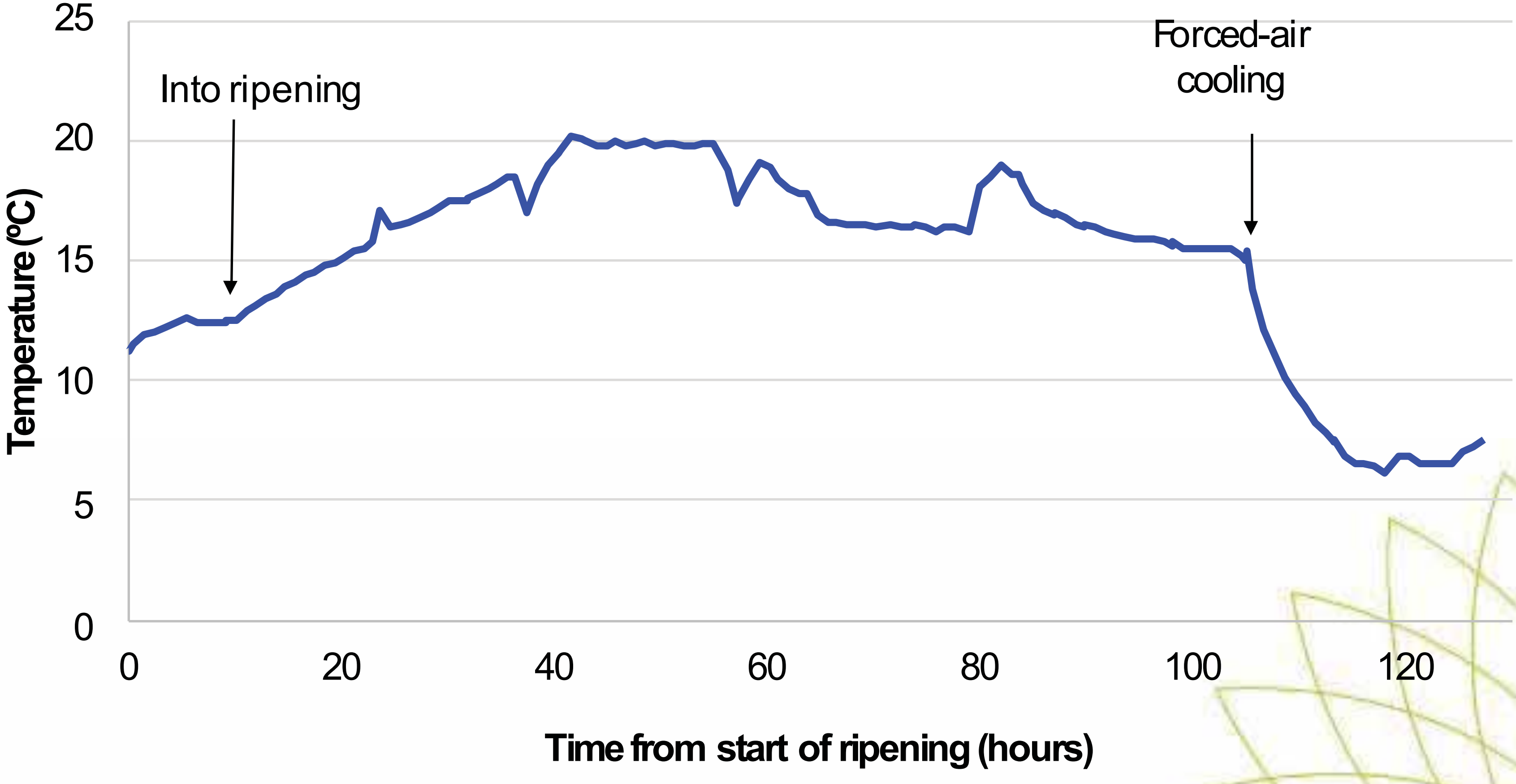
Packhouse B to ripener



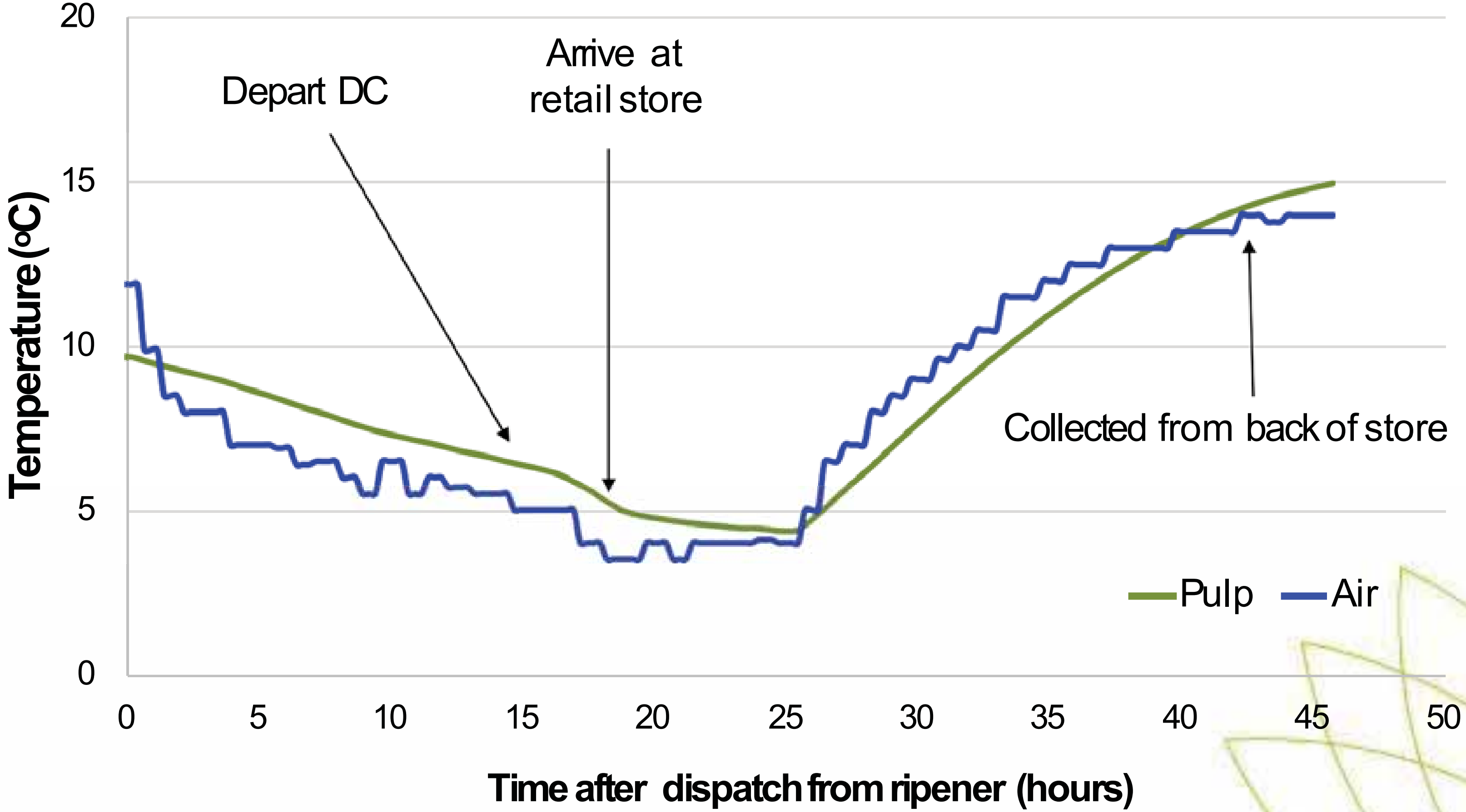
Packhouse A: Ripening



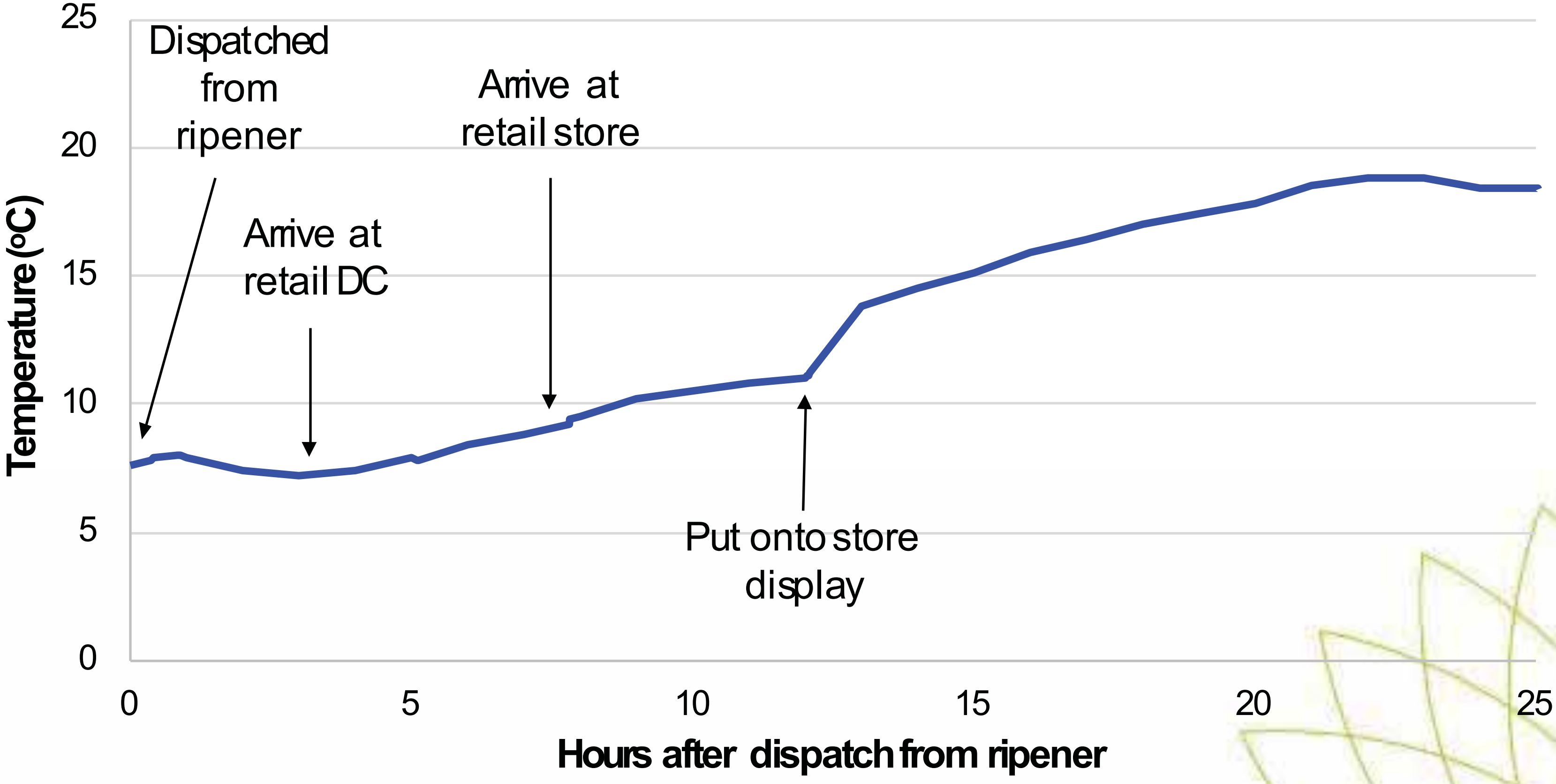
Packhouse B: Ripening



Packhouse A: Ripener to retail



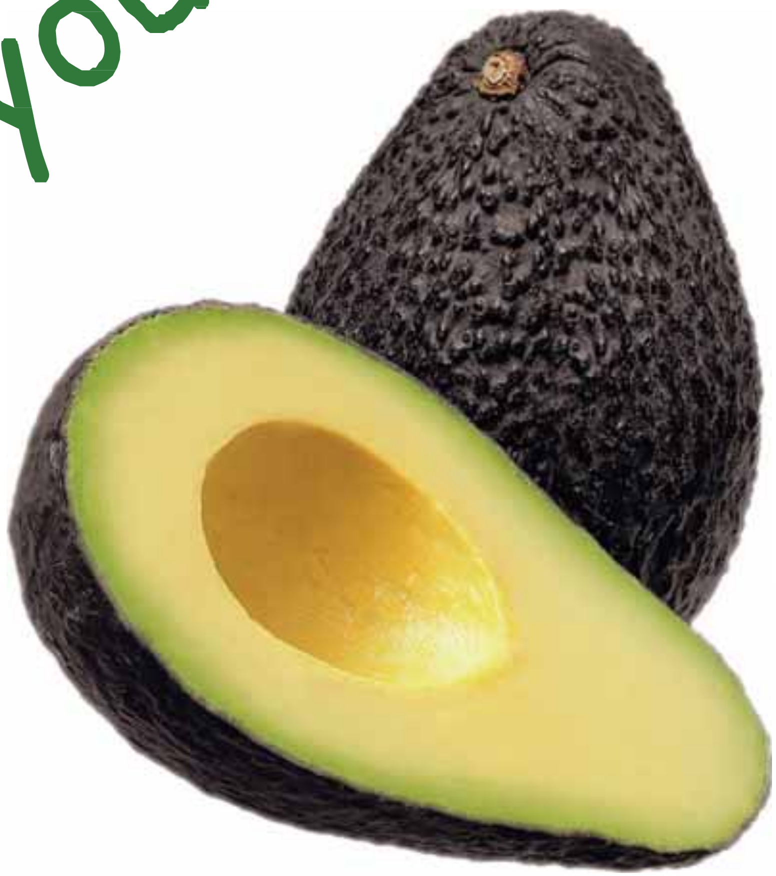
Packhouse B: Ripener to retail



Effect on quality

	Packhouse **A**	Packhouse **B**
Fruit with internal damage at packing	5%	1%
Average temperature during transport	**9.2°C**	**14.5°C**
Temperatures during ripening	17–18°C *Average 17.9°C*	12–20°C *Average 16.9°C*
Fruit with internal damage at dispatch from ripener	5%	**25%**
Fruit with internal damage at retail	0%	**30%**

Thank you



Hort Innovation
Strategic levy investment

AVOCADO FUND

This project has been funded by Hort Innovation using the avocado research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Avocado supply chain improvement projects are well underway

By Adam Goldwater, Applied Horticultural Research and Produce Marketing Australia

It is estimated that 20% of avocados – a whole 1 in 5 of carefully harvested, packed, transported and ripened fruit – is already damaged by the time it gets into the consumers shopping basket.

Reducing this damage would mean more happy customers, and more avocados purchased. Progress is now well underway to finding ways to reduce the level of damaged avocado fruit at retail, with the aim to limit bruising, rots and other postharvest injuries to no more than 10% within three years.

Two projects on supply chain quality improvement are being undertaken by Applied Horticultural Research (AHR) and Produce Marketing Australia (PMA).

Retail improvements

One of the immediate issues the team has examined is how consumers choose avocados, and how many they purchase. Consumer research was undertaken across 32 supermarkets and independents across Sydney, where shopper behaviour was examined when selecting avocados. The number of fruit squeezed and purchased by each shopper was recorded. This was compared in stores with good quality displays that were sorted by ripeness and contained ripe fruit, or stores with unsorted displays, and those with hard fruit only.

One of the immediate issues the team has examined is how consumers choose avocados, and how many they purchase.

The first thing a consumer does when they reach the avocado display is to pick up a fruit and squeeze it. Work conducted by DAF Queensland has shown that squeezing fruit results in bruises. They have also shown that these bruises are not visible immediately but develop over several days – right when the fruit is eaten.

***Figure 2.** TOP: this avocado display is difficult for consumers to select fruit from, resulting in more fruit squeezed, and less purchased. BOTTOM: by sorting fruit by ripeness, consumers can select fruit more easily, reducing squeezing and increasing sales.*

Consumers can end up squeezing many fruit before they decide to buy. We saw one customer squeeze 27 avocados before making a purchase decision. Many squeezed at least 10, and a few squeezed up to 20 and then walked away empty handed.

The factors that most increased squeezing were displaying all

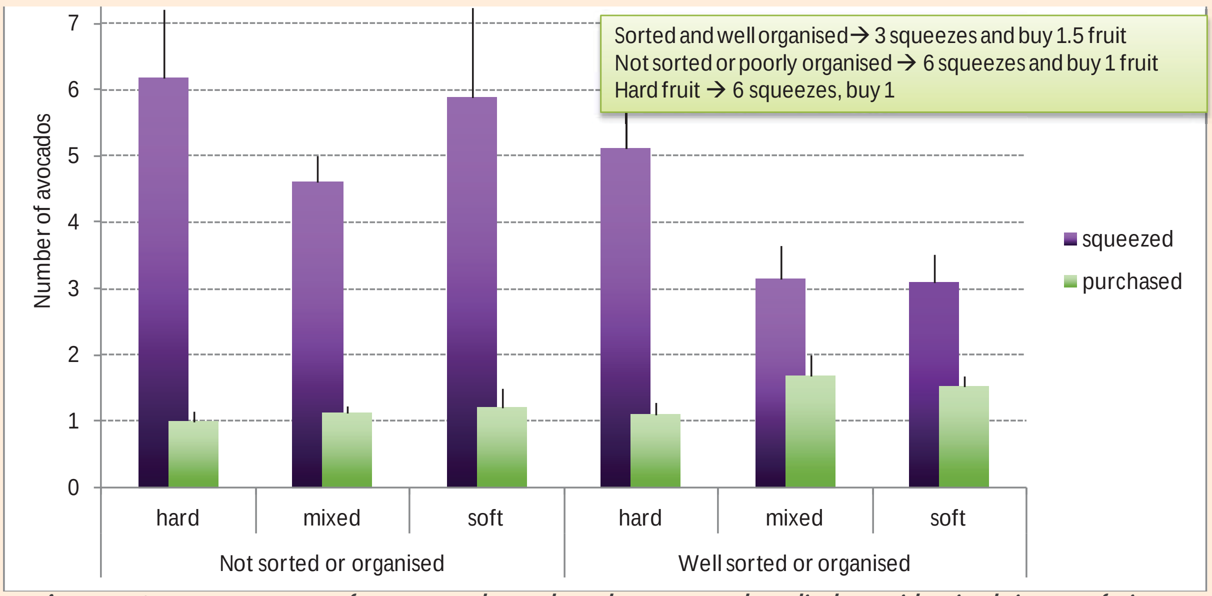


***Figure 1.** Consumers squeeze fewer avocados and purchase more when displays with mixed ripeness fruit are sorted by firmness, are well organised, and ripe fruit is available. Well organised means that displays had fruit neatly arranged to a maximum of 2 layers, as opposed to fruit randomly scattered or piled up.*

hard fruit, and not sorting the display. Both of these factors meant that consumers squeezed an average of six fruit. They then purchased either one hard fruit, or one to two fruit when displays of mixed ripeness were available (Figure 1).

Nearly 40% of consumers didn't buy any avocados at all when the only option was hard fruit.

In contrast, if the display had a mix of hard and ripe fruit, or all ripe fruit, then 75–80% of consumers bought avocados. Consumers nearly always bought two avocados from mixed ripe displays if the fruit was arranged to make this easy. However, if the display was unsorted, they only bought two avocados about half the time.

It seems clear that sorting displays into ripe and unripe fruit helps consumers choose avocados, increasing purchases and reducing damage from squeezing.

In the coming phase of the project, sorted displays marked with header cards with "Eat now", "Eat later" will be implemented in a number of retailers. Staff training will be provided on managing the displays, with independent assessment of how well they manage the different ripeness categories. The research team will also examine how this changes consumer behaviour in terms of both squeezing and purchase size. Both major and independent retailers have been strongly supportive of these retail merchandising concepts. After all, a happy customer is going to come back for more avocados!

Figure 3. *Growing practices and temperature control from orchard through to retail are the focus of the cool chain best practice adoption project.*

Cool chain improvements

Naturally, quality at retail is also affected by what happens while fruit is growing, and how it is managed during and after harvest. Poor orchard practices, rough handling, and poor temperature management, inevitably increase postharvest rots and internal quality issues (Figure 3).

AHR has undertaken a comprehensive review of research on factors that affect retail quality. This details how everything from soil preparation to drops during harvest affect the end product. Copies of the complete review are available on request for interested growers and packers (please email: *sandra.marques@ahr.com.au*).

Best practices identified through the review, as well as by working with growers and packers, will be detailed in a new cool chain best practice document. In brief, recommendations include:

Preharvest: reduce risk of postharvest rots through an effective fungicide program and maintain healthy trees;

Harvest: avoid dropping fruit, avoid picking when fruit are wet, clip rather than snap pick if disease pressure is high;

Packhouse: avoid delays in cooling between harvest and packing, use postharvest fungicide immediately after harvest, pick and pack within 24hrs, immediately forced-air cool fruit to 5-7ºC;

Transport: minimise breaks in the cool chain, maintain 5-7ºC, use temperature loggers to verify the system is working;

Wholesaler: minimise fruit age (days from harvest);

Ripener: ripen between 16-20ºC, using the lower end of the range for mature fruit at risk of rots, store sprung fruit at 5ºC, and minimise holding time;

Retail: store ripe fruit at 5ºC and minimise storage time.

The coming phase of the project involves working with packhouses around Australia to discuss these best practice recommendations, and identify feasible improvements that can be made, particularly around cooling practices. To request a visit from the project team, please contact Adam Goldwater (details below).

Acknowledgement:

Projects AV15010 Cool Chain Best Practice Adoption and AV15011 Retailer Point of Purchase Improvements are funded by Horticulture Innovation Australia Ltd using the Avocado industry levy and funds from the Australian government.

For more information contact: Adam Goldwater from Applied Horticultural Research at adam.goldwater@ahr.com.au or phone + 61 2 8627 1040; or John Baker from Produce Marketing Australia, *john@producemarketing.com.au* or phone +61 2 9642 1555

Avocado cool chain best practice adoption

Applied Horticultural Research

Growing the perfect avocado requires money, time and effort. While getting things right in the orchard is important, it is essential that the cool chain is managed well for that avocado to reach the consumer still in perfect condition.

The *Cool Chain Best Practice Adoption Project* (AV15010), undertaken by Applied Horticultural Research (AHR) has focussed on increasing adoption of best practice in the avocado cool chain, in order to increase the quality of avocados at retail. That has involved working closely with packhouses around the country to help identify practices that can be improved. In addition, new resources have been developed that will help all supply chain stakeholders to reduce risk and sell better fruit.

Packhouse studies

Temperature management and physical handling from harvest has been monitored in 12 major avocado packhouses in Queensland, New South Wales, South Australia and Western Australia.

Real-time location tracking temperature loggers were used to monitor temperature from harvest to the packhouse, during transport, ripening and in some cases, all the way to retail.

Physical impacts were monitored at harvest and on packing lines using an impact recorder.

Adding pulp temperature loggers to picking bins in the orchard

Impacts at harvest

Even hard-green fruit are still susceptible to external bruising and skin damage. We wanted to know what impacts could occur during harvest, and how those related to impacts known to potentially damage fruit.

An impact recording device (IRD) was used to compare the forces experienced by fruit when picking into ground bags versus half-depth or full-depth mechanical work platform (cherry picker) bags. Impacts of 200G are equivalent to a drop of around 10cm onto concrete, while an impact of 250G is similar to a 20cm drop. Hard, green avocados can develop skin damage from a 10cm drop, while a 20cm drop increases the risk of rots and external bruising in ripe fruit.

Fruit fell approximately 1m when harvesting into full-depth mechanical work platform bags. These impacts averaged over 200G, with some over 250G! However, if the drop is reduced using rope extenders on the bags, impacts are reduced to safe levels (*Figure 1*). Harvesting into ground bags also limits fruit damage.

Impacts along the packing line

It was good to find that there were very few potentially damaging impacts along packing lines. Most were generally flat, with plenty of foam padding and baffles to soften direction changes and drops. The one point of major difference between packhouses was the bin tip. Bin tippers with covers that gradually release fruit recorded much lower impacts compared to those left uncovered.

Impact recording device moving along a packing line

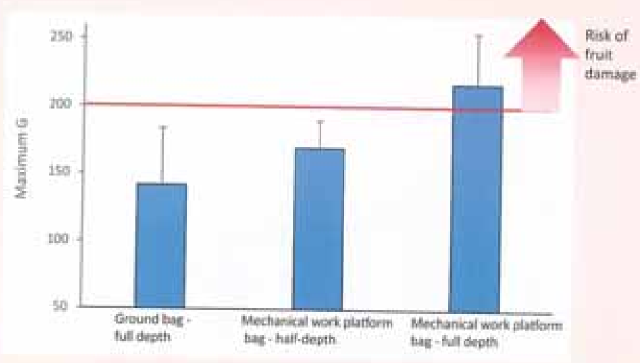


***Figure 1:** Harvesting fruit into full-depth mechanical work platform bags with a single layer of fruit in the bottom (1m drop) exceeds the impact level that can result in external bruising or skin damage. Halving the height of the bag using baffles (or rope extenders on the bags), or using ground picking bags will eliminate most of this damage (AHR data)*

Fruit cooling in picking bins

Fruit that cannot be packed within 24 hours of harvest should be cooled before packing, especially if the avocados have been picked hot. In many packhouses this is done by simply placing bins in the coolroom. This poses a problem, as fruit in the middle of picking bins cools at a much slower rate than those in the top of the bin. The result is that warm fruit in the middle of the bin may start to ripen, while those on the outside of the bin remain cool and firm.

Forced air systems can overcome this issue, cooling fruit rapidly, evenly and without condensation (Figure 2). While forced air is more commonly used to cool packed and palletised fruit, it can work even better with bins.

Transport temperatures – a cause for concern

Nearly all of the supply chains monitored had temperatures well above the optimal (ie 5°C for Hass). In many cases, the cooling capacity/air circulation in the truck trailer could not prevent product warming during the trip, with avocados arriving at the wholesale markets at 12°C or even higher (*Figure 3*).

Most trucks can only maintain temperature, not reduce it. In some cases, product was not thoroughly cooled before loading, resulting in avocados staying warm for the whole trip. Temperature should be monitored in all loads using readily available single or multi-use air temperature loggers.

New best practice materials

The avocado industry identified a need for updated and more detailed postharvest guidelines. AHR has developed four new resources in consultation with growers, packers, transporters, wholesalers and retailers. The resources will be available online in the Best Practice Resource, and as printed resources in coming months. Requests for copies can be made in advance by email to *sandra.marques@ahr.com.au*. The resources are:

1. Review of best practice – a detailed review of Australian and international research of pre and postharvest factors affecting quality of avocados
2. Supply chain best practice guide – a concise guide for recommended postharvest best practice from orchard to retail
3. Postharvest problem solver guide – focusing on fruit quality issues
4. Check lists – a series of risk-preventing check lists for each stage of the supply chain.

Extension rollout

The final phase of the project involves a rollout of the extension materials to major avocado growing regions. To get your copies of the new materials, and discuss the best practice recommendations with the project team, come along to a workshop in your region during the coming months. Dates will be advertised shortly through Avocados Australia.

Acknowledgement

The ***Cool Chain Best Practice Adoption Project*** (AV15010) is funded by Hort Innovation using the Avocado industry levy and contributions from the Australian Government.

More information

Adam Goldwater from Applied Horticultural Research at *adam.goldwater@ahr.com.au* or phone 02 8627 1040

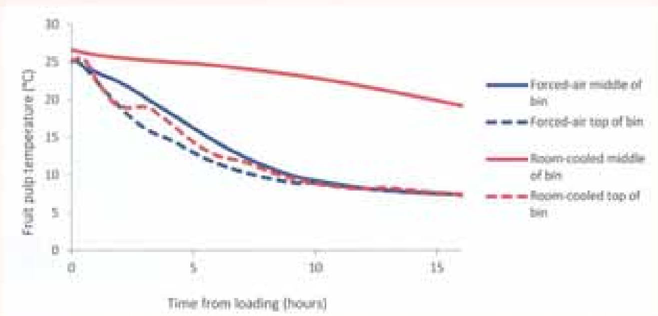


Figure 2: Pulp temperature of avocados in the middle (solid line) or top (broken line) of picking bins forced-air or room-cooled within the same storage room. A large temperature gradient developed between the middle and outside of the room-cooled bin. In contrast, fruit in the forced-air system cooled quickly and evenly (AHR data)

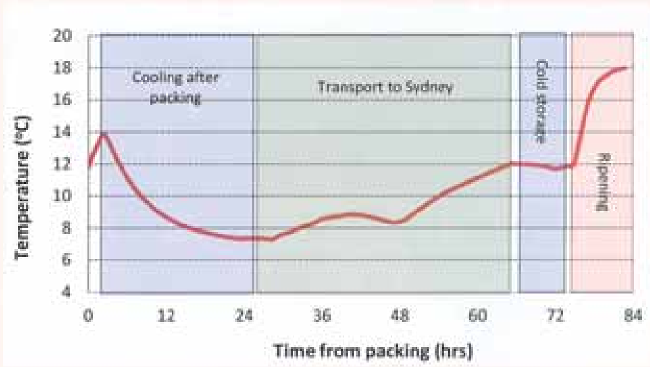


Figure 3: Typical temperature management from packing to ripening. Fruit warmed from 7°C to 12°C during transport to the ripening facility in Sydney (AHR data)

New avocado supply chain resources

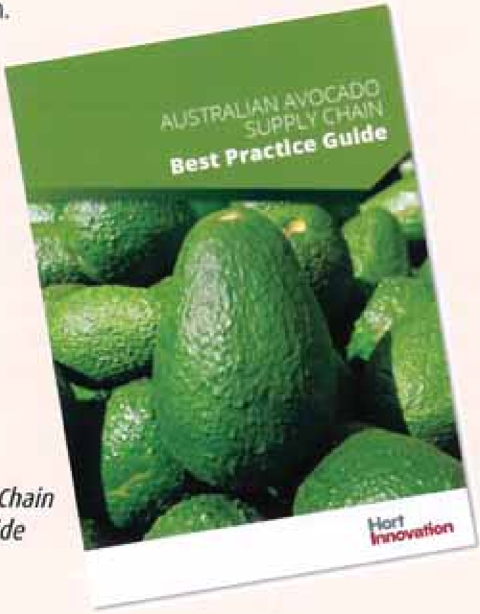
Adam Goldwater, AHR

Four exciting new resources have been developed for the Australian avocado industry.

While previously developed materials for the industry have all been valuable sources of technical information for stakeholders, some gaps were identified in post-harvest materials and therefore updates were required to incorporate new research and technology.

The aim of the supply-chain-focused material is to increase awareness of post-harvest factors affecting avocado quality, and ensure the supply of consistent, high-quality fruit to customers.

The new resources include something for everyone, with a supply-chain best practice guide, a fruit-quality problem solver manual, supply-chain checklists and a review of postharvest avocado research.



Australian Avocado Supply Chain Best Practice Guide

This guide summarises best practice recommendations from grower to transporter to retailer.

It includes guidelines on how the key factors affecting avocado quality can be managed to supply consistently high-quality fruit. It also demonstrates (at each stage of the supply chain) how losses in quality can occur if best practice is not followed.

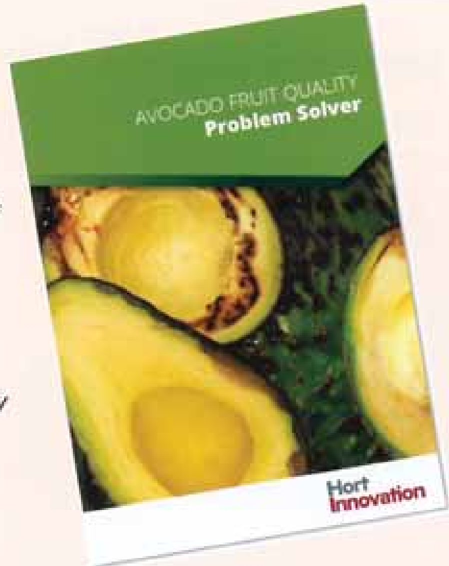
The guide has a strong focus on temperature management, which is one of the most critical factors in maintaining postharvest quality.

Avocado Fruit Quality Problem Solver

Designed to be used in conjunction with the best practice guide, it outlines the major fruit quality issues that can occur as avocados travel through the supply chain.

The focus is on postharvest issues and includes external and internal defects as well as ripening- and storage-related problems.

The problem solver can be used to help you identify a problem, find out what is causing it and how to minimise or prevent it.



Avocado Fruit Quality Problem Solver

Australian Avocado Supply Chain Checklists

The checklists summarise the key actions needed to maintain the postharvest quality of avocados.

A number of records are suggested, as a way of ensuring activities are correctly performed and recorded.

Space is left for the business to determine which processes have the highest priority and the status of each activity can be noted by the relevant staff.

The checklists should be reviewed regularly to allow system improvements from month to month and season to season.

New avocado supply chain resources continued

Review of Best Practice

There is an opportunity to dig deeper into factors affecting post-harvest quality of avocados via a detailed review of international avocado research.

With thousands of peer-reviewed papers written on post-harvest management of avocados, this document summarises that information in an easy-to-read format.

Workshops coming to you

To get your copies of the new resources, and learn more about them, come along to a workshop in your region during the coming months.

Lessons from packhouse and supply chain studies from across the country will be presented, including how harvest practices can reduce quality, how to get the most from fungicides and sanitisers, investigating whether to pre-cool or not to pre-cool, and checking whether you're getting the transport temperatures you paid for.

Workshop dates are:

- Renmark, SA – 21 May
- Mareeba, Qld – 31 May
- Stuarts Point, NSW – 5 June
- Childers, Qld – 7 June

Requests for printed copies of the resources can be made by email to: *sandra.marques@ahr.com.au.* The four resources will also be available for download from the library section of the Avocados Australia Best Practice Resource.

Acknowledgement

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AV15010 Avocado supply chain improvement project

MERI Management Plan

Revision 1.1: 26th November 2016	Last edited: GSR

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1 MERI Plan

The Monitoring, Evaluation, Reporting and Improvement process is imbedded in the project as part of the continuous improvement cycle undertaken by the governance and management groups.

The Project Advisory Group is primarily concerned with monitoring and evaluation how the project is contributing to the higher level impacts of the two goals. The composition and terms of reference for this committee is manage by Hort Innovation.

The AHR Management Team meets monthly and reviews the effectiveness and appropriateness of the activities. The Management Team are responsible for the detailed planning and improvement of the project.

Below the key evaluation questions are detailed together with how these will be monitored over the life of the project.

1.1 Impact

The table below outlines the specific evaluation questions to determine the impact of the project. The results will be evaluated by the Project Reference Group who will work with the AHR Management Team in considering any alteration to the project plan.

Evaluation Questions	What aspects of the project will be measured and tested?	How will these be monitored and how often?
Impact - *What has changed or is different as a result of this project? This could include the extent of change to natural resource condition, management practices or institutions. Impact could be positive or negative.* **Project Specific Evaluation Question/s**		
Increase adoption of cool chain best practice to reduce the level of damaged avocado fruit at retail from the current 25% (industry estimate) to no more than 10% within five years.	The quality of fruit will be measured at retail and involves detailed assessment of 10 fruit per store, measuring % damage, rots, bruising, fruit display characteristics, variety, origin, grower/packer where possible.	*Fruit quality will be measured in two ways. First the impact of specific changes in practice and then secondly at 2-monthly intervals in the implementation phase. Aim for 8 stores x 10 fruit each per assessment.*
	The temperature of fruit will be monitored through the supply chain as part of the implementation phase. We expect to work closely with 10 major packhouses as part a strategy to drive practice change. Fruit quality which has passed through these packhouses will be assessed at retail.	*Ten packhouses to be monitored for fruit temperature through the supply chain and focussed around proactive change innovations. .*
	Record of growers, packers and other supply chain members who attend training activities	*Link to training events .*
	Longer term impact. Fruit quality at retail, as per point one above should be measured beyond the time frame of the current project. It may take 5 years for the full impact of improvements to become apparent.	*This would require a separate project. Suggest measure 8-10 retail stores every two months for 5 years.*

Evaluation Questions	What aspects of the project will be measured and tested?	How will these be monitored and how often?
Revamp the industry best practice support materials to a standard that meets industry requirements.	The suitability and effectiveness of the revised best practice materials with key industry stakeholders.	*Consult with each industry group: Orchard, Packhouse, Transport, Wholesale, Ripening and Retail. Undertake assessment and before and after each intervention.*
	The success of the change program across the supply chain for uptake of best practice by all sectors from orchard to retail.	*Ask the stakeholders what they think of the revised best practice materials. Undertake assessment and before and after each intervention.*

1.2 Effectiveness

The table below outlines how the project effectiveness will be monitored. The results will be evaluated by the AHR Management Team in considering any alteration to the project plan. The dates for the delivery of outputs will be taken from the Annual Work plan.

Evaluation Questions	What aspects of the project will be measured and tested?	How will these be monitored and how often?
Effectiveness - *To what extent were the planned activities and measures achieved? What, if any, lessons have been learned that could improve the success of future projects?* *To what extent did the project achieve the desired result within budget and timeframes?* **Project Specific Evaluation Question/s**		
Have the best practice materials and research been reviewed?	Has the review of best postharvest innovations been completed and documented (Task 2)?	Final Internal report completed.
	Have the Australian and international best practice materials been reviewed and documented (Task 3)?	Final Internal report completed.
	Have the factors responsible for causing internal been reviewed and documented (Task 4)?	Final Internal report completed.

Evaluation Questions	What aspects of the project will be measured and tested?	How will these be monitored and how often?
	Have disease management options for avocadoes been reviewed and documented (Task 5)?	Final Internal report completed.
Have the barriers to adoption been identified?	Has the audit of avocado supply chain members been conducted, and analysed, identifying the main to adoption of the current best practice materials? (Task 6).	Consultation complete and documented. Data analysed and main adoption barriers identified for each industry group, and reviewed by the PRG.
Has the change program been developed?	Change program across the supply chain developed to drive uptake of best practice by all sectors from orchard to retail (Task 8.1).	Change program developed and reviewed by the PRG.
Have the delivery options been determined and communication strategy planned?	Best delivery options for each industry sector to address barriers determined, communicated with industry and integrated into the AAL communications strategy (e.g. website and other industry comms activities).	Delivery plan developed, reviewed and accepted by the PRG, and AAL.
Have best practice materials revised?	Refresh best practice resources for all sectors of the supply chain have been revised.	Materials produced and reviewed by the PRG. Compatible with the revised AAL delivery platform.
Has the change process been implemented?	Change program has been Implemented across the supply chain.	Has the production of new material commenced, and associated training and evaluation activities.

Evaluation Questions	What aspects of the project will be measured and tested?	How will these be monitored and how often?
Has the project had any impact on the quality of fruit at retail?	Measure the impact of specific activities on fruit quality at retail. For example, monitoring temperatures of fruit in the supply chain and relate fruit quality at retail to temperature management. The second approach is to measure the quality of fruit generally – this is a broader task and may require a longer-term evaluation project.	Measure 6-8 sets of 10 fruit per activity. To be demined.

1.3 Effectiveness, Appropriateness & Legacy

The table below outlines how the project efficiency and appropriateness will be monitored. The results will be evaluated by the AHR Management Team in considering any alteration to the project plan.

Evaluation Questions	What aspects of the project will be measured and tested?	How will these be monitored and how often?
Appropriateness - *To what extent has the innovation being tested contributed useful information to address the goals?* *To what extent did the activities and the way they were undertaken align with stakeholder needs and expectations?* *Which innovation practices or technology employed did not contribute to / deliver on outcomes? And why?* Project Specific Evaluation Question/s		
Did the reviews provide the necessary evidence for the design of other project components?	The design of delivery and research components of the project based on the evidence and recommendations provided in the reports	Recommendations reviewed by the management team.

Evaluation Questions	What aspects of the project will be measured and tested?	How will these be monitored and how often?
Training and extension activity has increased the skills and knowledge of growers and advisors.	Self assessment of skills and knowledge.	An assessment of participants at each training and extension activity to be undertaken and reported to the project Management Team
Does the demonstration of impact on an intervention on fruit handling or crop management motivate supply chain members to improve practices?	Interview supply chain members and assess fruit quality at retail.	Target fruit that relates to the intervention.
Is working with the top 10 packhouses and effective strategy to bring about practice change and adoption of improved practices?	Assess the impact of fruit quality at retail following an intervention.	Relate to the intervention.
Have the new best practice resources been effective ?	Measure impact and acceptance of the revised materials	Metrics included in milestone reports
Have the new resources been incorporated into supply chain activities?	Measure uptake and use of new materials	Record number of copies requested (hard copy) or accessed (soft copies) and use of electronic resources using standard metrics.

1.4 Testing Assumptions

The Program Logic identifies six key Assumptions underpinning the project. This section outlines how these assumptions will be measured and monitored over the course of the project.

Evaluation Questions	How will the assumption be measured and tested?	How will these be monitored and how often?	How will the results be evaluated? Who by?
Assumption 1: *Good strategic and tactical plans reviewed by industry will ensure the project team deliver on the project goals*	Approval of strategic and yearly tactical plans with outputs reported in milestone reports will ensure outputs are delivered over the life of the project.	How well the project outputs are delivering on the project goals will be progressively assessed at the PRG meetings.	Final project assessment will be undertaken to quantify how the project delivered on the 2 goals.
Assumption 2: *The quality and presentation style of the current best practice materials is a significant factor in variable fruit quality at retail.*	Improving materials and measuring impact on quality at retail.	Assess fruit quality at key points and after project end.	Fruit quality assessment at retail, and the level of use of revised best practice materials.

Evaluation Questions	How will the assumption be measured and tested?	How will these be monitored and how often?	How will the results be evaluated? Who by?
Assumption 3: *Avocado supply chain members have the capacity and motivation to improving management disease, production and cool chain using the project tools, training and information.*	Growers motivated and interesting to *attend* training and extension activities and make use of resources produced by the project.	Training activity attendances recorded. Downloads of documents and engagement with electronic communications.	Metrics reported in 6 monthly milestone reports.
Assumption 4: *The extension tools will create momentum among the Avocado industry so that a wider group of growers will improve growing, packing, cool chain and through using resources developed by the project.*	Growers beyond those directly involved in the project change their practices.	End of year 2, follow up survey of a sub-sample of growers to determine practice change.	PRG will evaluate the results of the survey and other information on the adoption of improved management practices in the final year.
	Practice change will be assessed by measuring uptake with a focus on collaborating packhouses. This will be used to estimate the value to the Avocado industry of improved management of the Avocado supply chain.	Use a case study approach to measure impact.	Results will be presented to the PRG.

Evaluation Questions	How will the assumption be measured and tested?	How will these be monitored and how often?	How will the results be evaluated? Who by?
Assumption 5: *There are new approaches to managing fruit diseases which need to be refined and tested in Avocado crops before growers and advisors will consider their use.*	The development of new fruit disease management practices and their incorporation in project delivery outputs.	New practices will be documented along with their efficacy in each milestone report	Yearly by the PRG.
Assumption 6: *If supply chain members, including retailers, clearly understand the financial benefits that would follow if they do their part to reduce the amount of damaged fruit on retail displays, this would motivate them to make the changes required.*	Case studies/success stories which include economic data will be based on this idea.	Feedback from industry surveys and community of practice.	At the end of the project by the project team and the PRG.