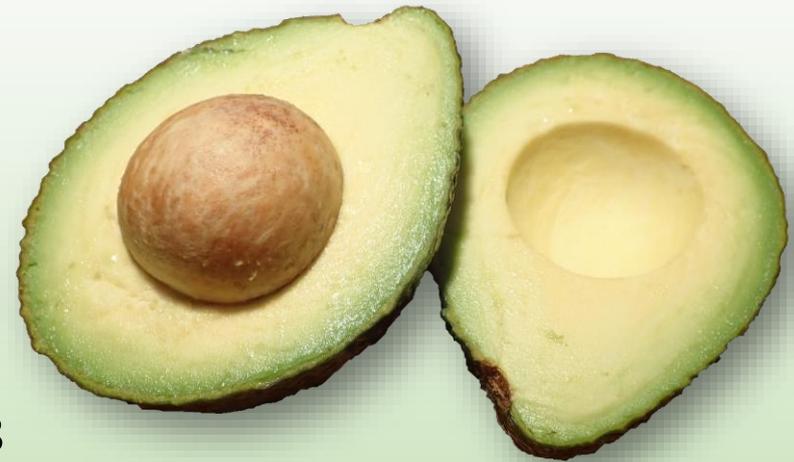


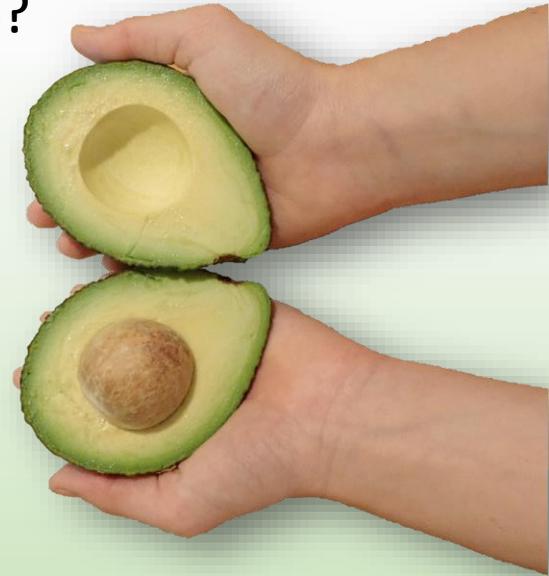
# AV15009 Technologies and Practices to Reduce Bruising

Industry update  
Avocados Australia Regional Meeting  
Sunshine Coast, Queensland, 2 May 2018



# Overview of presentation

- Background
- Project scope
- What is flesh bruising and how is it measured?
- What contributes to flesh bruising in avocado?
- Does impact injury also promote body rots?
- What can be done to reduce bruising?
- Spreading the message
- Where to next?
- Concluding remarks



# Background

- Flesh bruising is responsible for around **half** of all avocado internal defects detected at the retail level<sup>1</sup>
- Defects affecting more than **10%** of the flesh can negatively affect consumers' repeat purchasing<sup>2</sup>
- Handling by retailers and shoppers is the main cause of flesh bruising at retail<sup>3</sup>
- Post-purchase handling by consumers causes further bruising<sup>3</sup>



Bruising in 'Hass' fruit handled once by each of 20 different shoppers

1. Tyas, J. (2016). Avocado industry fruit quality benchmarking. Final report AV11015. Horticulture Innovation Australia, Sydney.

2. Harker, F.R., et al. 2007. Australian consumers' perceptions and preferences for 'Hass' Avocado. Final report AV06025. Horticulture Australia Ltd, Sydney.

3. Joyce, D.C., M.S. Mazhar, and P.J. Hofman (2015). Understanding and managing avocado flesh bruising. Final report AV12009. Horticulture Australia Limited, Sydney, Australia.

# Background

- **97%** of Australian avocado consumers admit to squeezing fruit to test ripeness<sup>1</sup>
- Shoppers handle **3 times** more avocados than they buy<sup>2</sup>
- Awareness of shoppers regarding their contribution to bruising seems to be increasing...

Five years ago...

42% of shoppers agreed that “bad” avocados have been handled or touched too much<sup>1</sup>



Now...

92% of shoppers know that squeezing avocados too hard causes bruising<sup>3</sup>

1. Jones, T. (2014). Project avocado education QN. Final report AV12035. Horticulture Australia Limited, Sydney.

2. Joyce, D.C., M.S. Mazhar, and P.J. Hofman (2015). Understanding and managing avocado flesh bruising. Final report AV12009. Horticulture Australia Limited, Sydney, Australia.

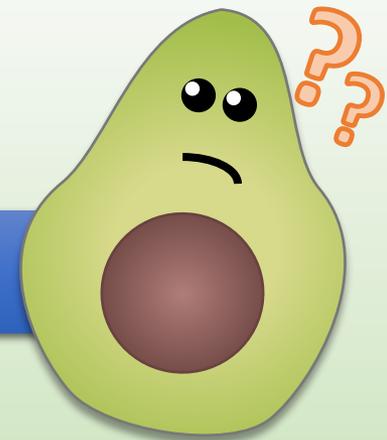
3. Quantum Market Research (2017). Avocado buyer segmentation. JN17051. Hort Innovation, Sydney.

# Background

But inconsistent quality remains an issue...

- Around **1 in 5** avocados at retail level do not meet consumer expectations for quality<sup>1</sup>
- **45%** of avocado shoppers at least sometimes felt dissatisfied with the quality once they had cut into an avocado at home<sup>2</sup>

What is the solution?



# Scope of project AV15009

## Objectives:

- To qualify influences and interactions that cause and contribute to flesh bruising
- To qualify, develop and promote tools and technologies for reducing flesh bruising at retail

## Activity areas:

- Review contributing factors to fruit **susceptibility to bruising** to identify gaps in research
- Review relationships between **disease and flesh bruising** to identify gaps in research
- Document **best practice** to prevent fruit bruising at retail for implementation in retail education
- Develop and test **alternative technologies** that reduce handling by retailers / consumers

# AV15009 project team



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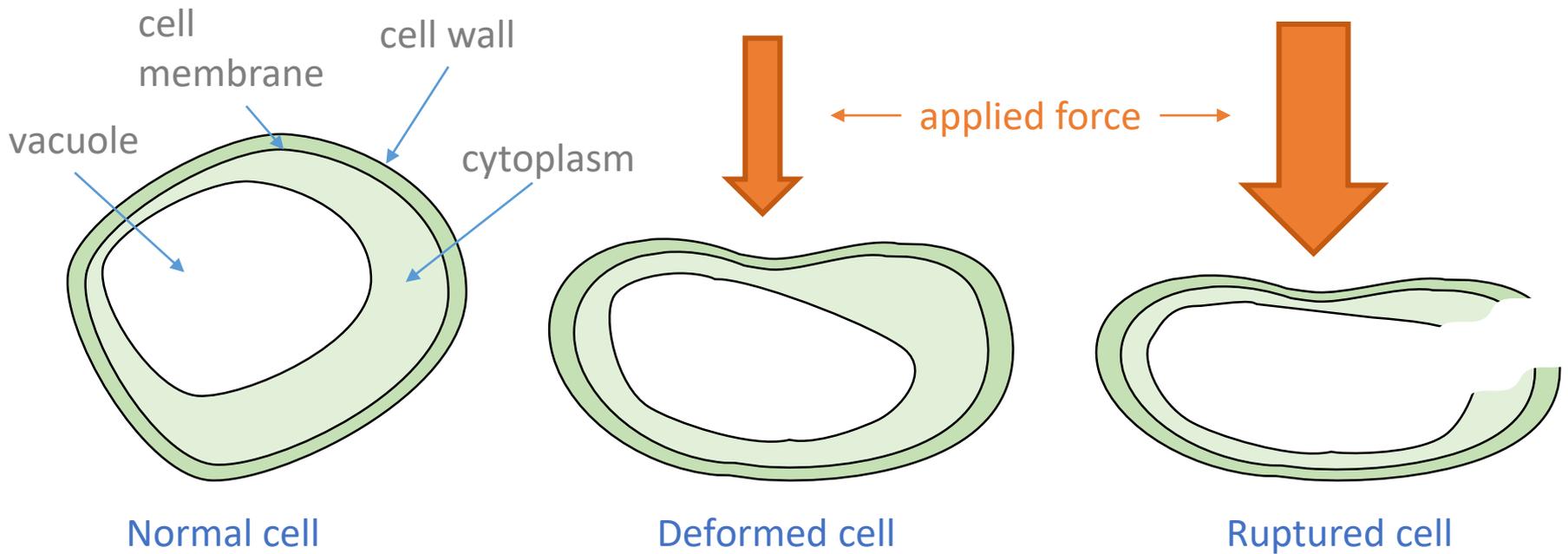


Melinda Perkins  
(UQ)

Project Team  
Members

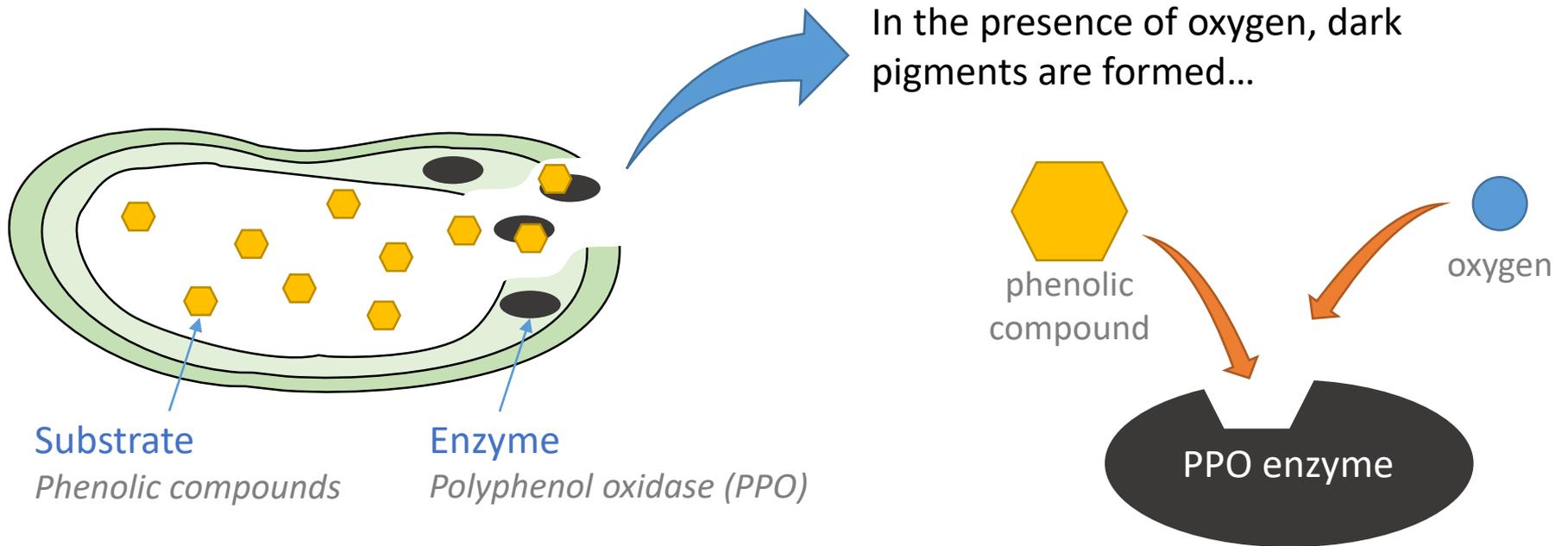
# What is flesh bruising?

The bruising process at a cellular level...



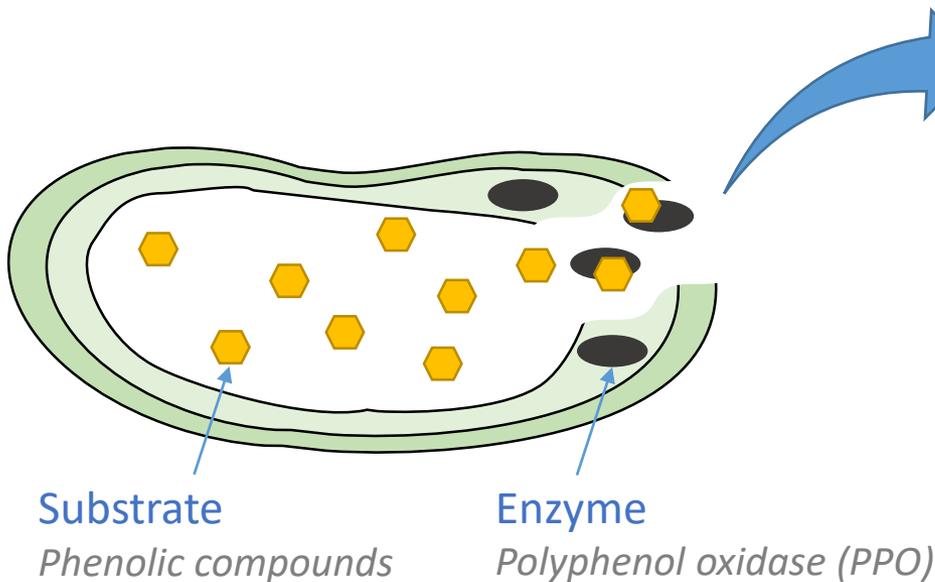
# What is flesh bruising?

Cell damage brings together browning enzymes and their substrates...



# What is flesh bruising?

Cell damage brings together browning enzymes and their substrates...

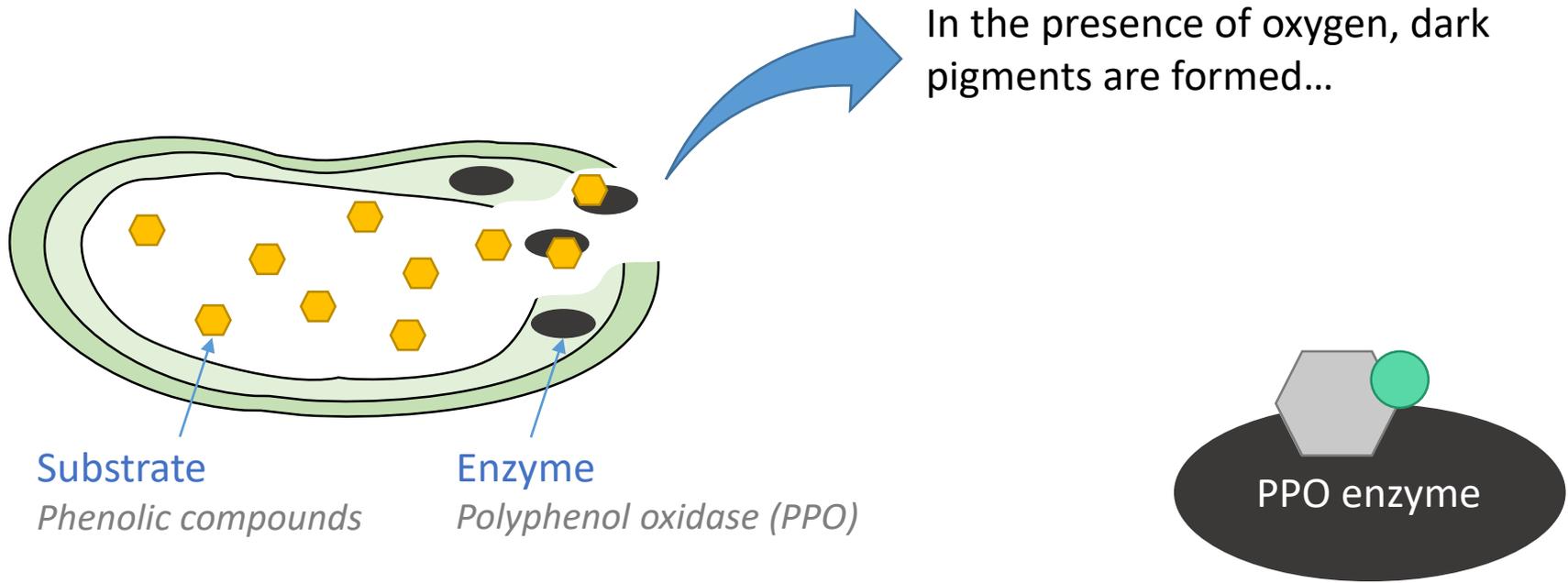


In the presence of oxygen, dark pigments are formed...



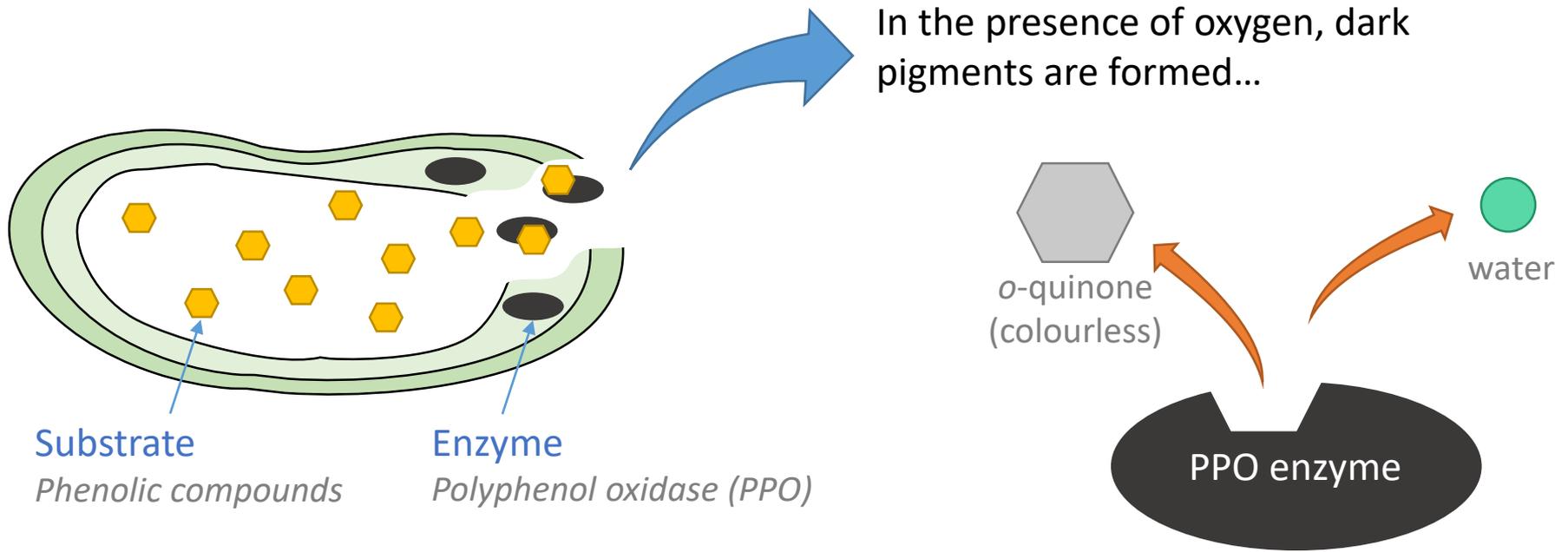
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Cell damage brings together browning enzymes and their substrates...



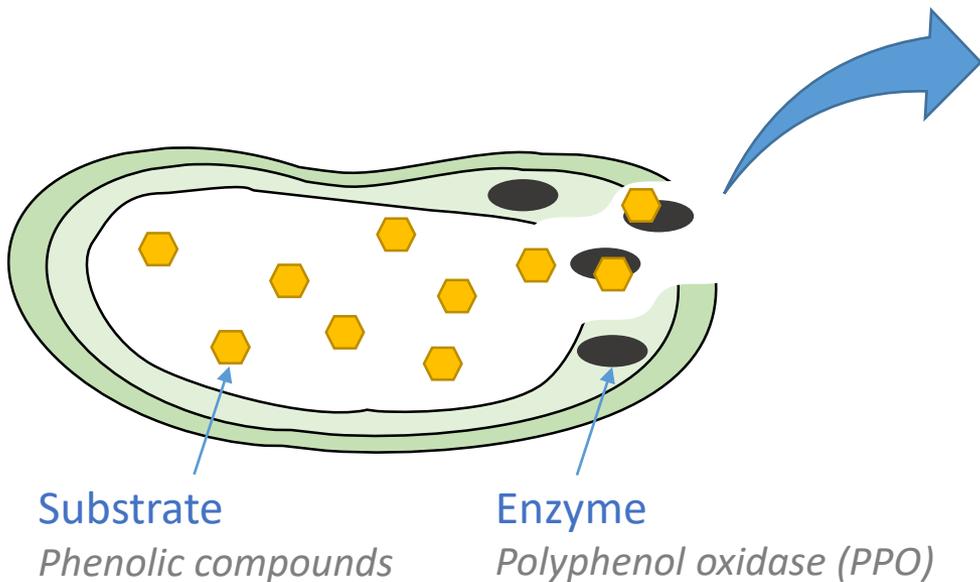
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Cell damage brings together browning enzymes and their substrates...

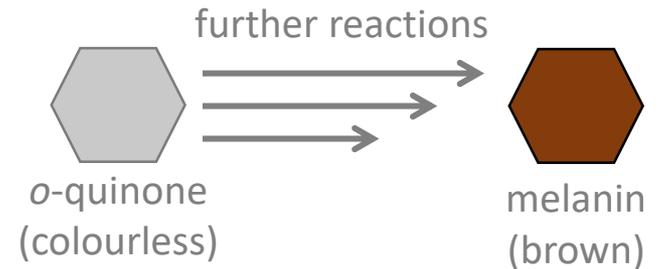


# What is flesh bruising?

Cell damage brings together browning enzymes and their substrates...

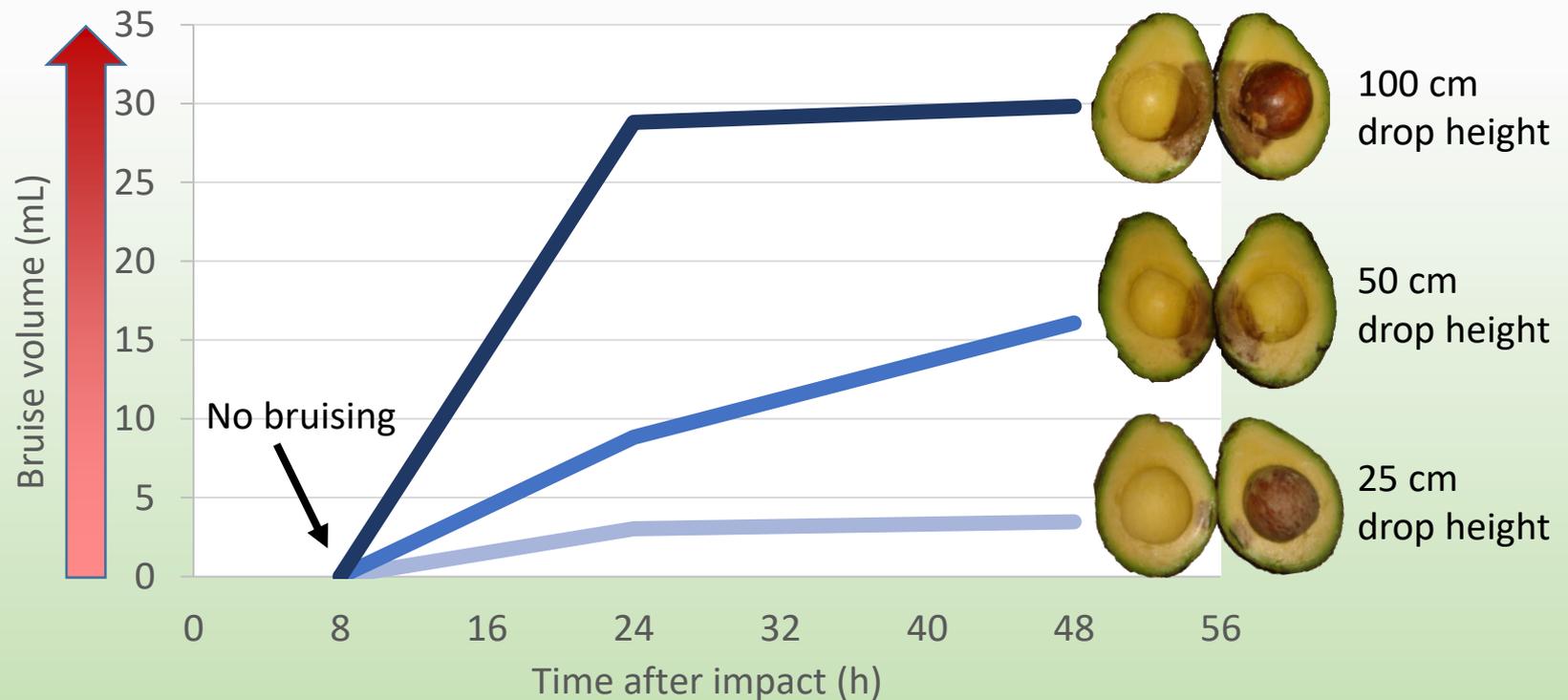


In the presence of oxygen, dark pigments are formed...



# What is flesh bruising?

- Rate of browning also depends on temperature and pH
- At 20°C, visible bruising can take 24 hours to develop



# How is flesh bruising measured?

## Bruise incidence

- Number of bruised fruit in a given sample (e.g. tray) of fruit

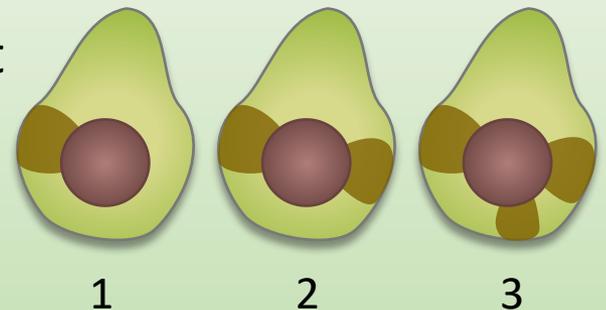
*Often expressed as a percentage of the total number of fruit*



3 out of 10 = 30% incidence

*OR...*

- Number of bruises on an individual fruit



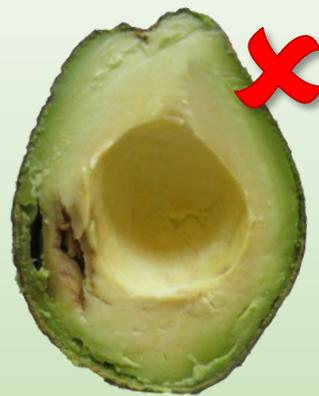
# How is flesh bruising measured?

## Bruise severity

- Volume or area of bruised flesh in individual fruit
- May be converted to a percentage of the total fruit flesh volume or area of cut surface
- 10% bruise area is generally considered unacceptable to consumers



5%



10%



15%

# How is flesh bruising measured?

## Bruise intensity

- Relative darkness of a bruise

*Can be scored visually (e.g. light brown to black) or measured with a colour meter*

## Bruise susceptibility

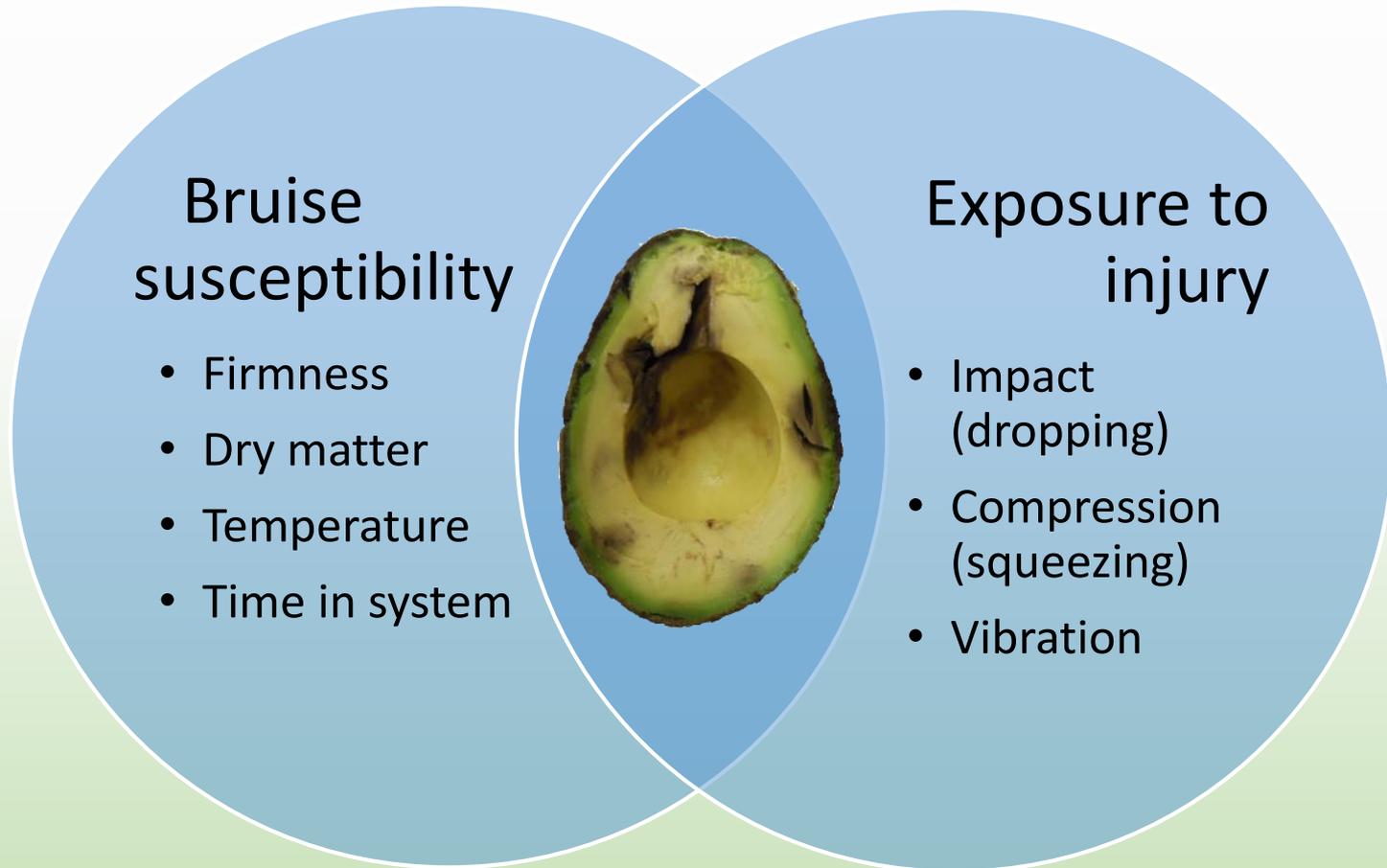
- Degree of ease or difficulty by which a fruit bruises

*Expressed as ratio of bruise volume to impact energy*



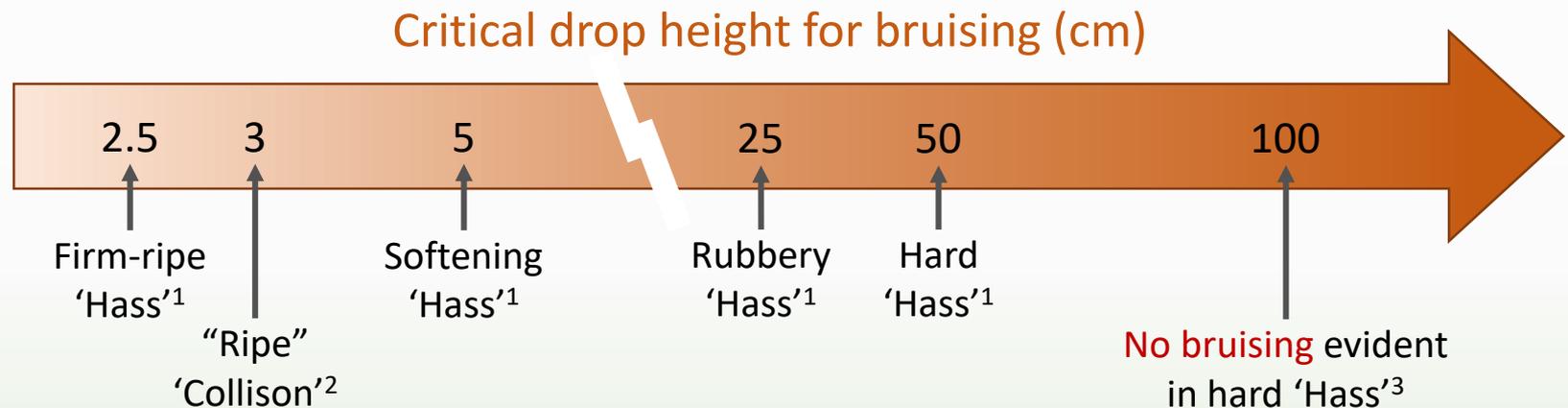
Using a colour meter to measure bruise intensity

# What contributes to flesh bruising in avocado?



# What contributes to flesh bruising in avocado?

- Firmness



- Dry matter

↑ dry matter = ↓ bruise susceptibility in firm-ripe 'Hass' avocados subjected to a 50 cm drop height<sup>4</sup>

*Bruise volume progressively decreased as dry matter increased from 22 to 33%*

1. Ledger, S.N., Barker, L.R., 1995. Black avocados - the inside story, Australian Avocado Growers Federation Conference - The Way Ahead, pp. 71-77.

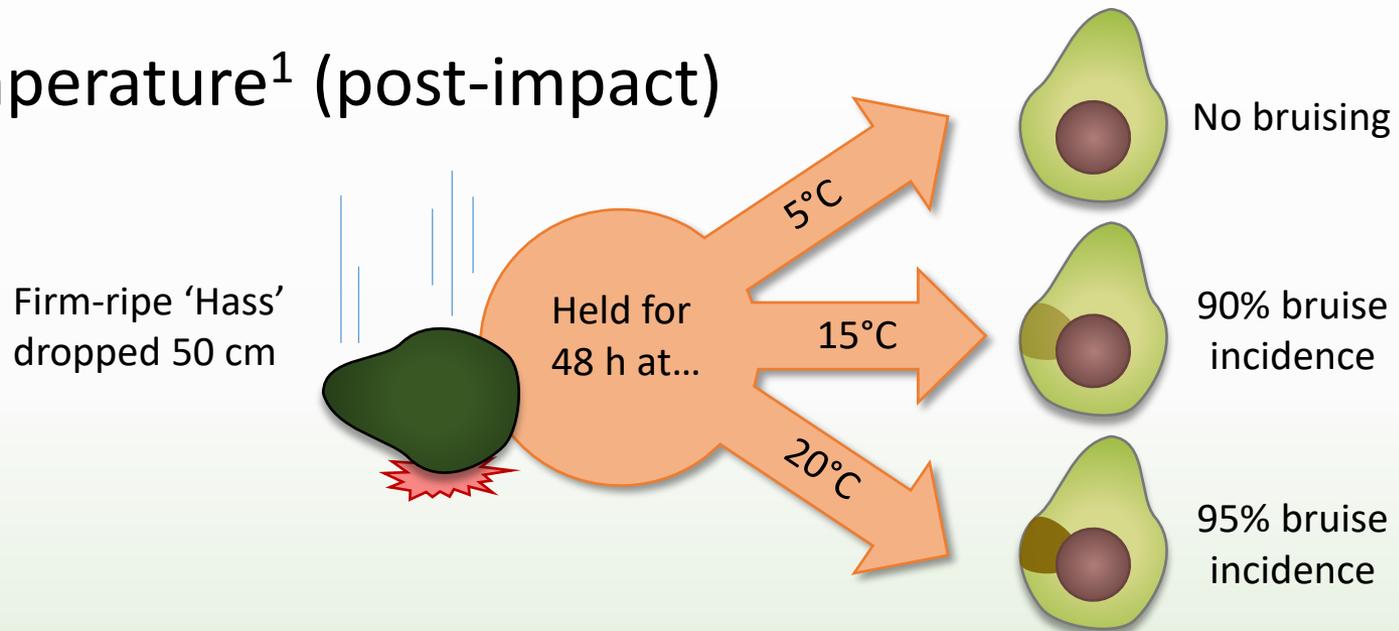
2. Baryeh, E.A., 2000. Strength properties of avocado pear. Journal of Agricultural Engineering Research 76, 389-397.

3. Mazhar, M., et al. (2015). Non-destructive 1H-MRI assessment of flesh bruising in avocado (*Persea americana* M.) cv. Hass. Postharvest Biology and Technology 100, 33-40.

4. Joyce, D.C., et al., 2015. Reducing flesh bruising and skin spotting in 'Hass' avocado. Final report AV10019. Horticulture Australia Ltd, Sydney.

# What contributes to flesh bruising in avocado?

- Temperature<sup>1</sup> (post-impact)



*20°C > 15°C for bruise intensity*

- Time in system<sup>1</sup>

Storage at 5°C for 1 to 5 weeks prior to ripening increased bruise susceptibility of firm-ripe 'Hass' fruit *(vs fruit not stored)*

↑ storage duration = ↑ bruise volume

# What contributes to flesh bruising in avocado?

## Other factors likely to be involved

- Pre-harvest water stress

*Increases PPO activity in avocado fruit at “eating ripeness”<sup>1</sup>*

- High turgor pressure at harvest

*Causes greater lenticel damage in avocado fruit<sup>2</sup>*

*Linked to increased bruise susceptibility in apple and pear<sup>3</sup>*

- Mineral nutrient balance

*Calcium is important for cell wall strength and membrane stability*

*Low calcium and/or high nitrogen in avocado fruit → poor quality*

↑ body rots<sup>4,5</sup>, vascular browning<sup>6,7</sup> and mesocarp discolouration<sup>4,6</sup>

↓ firmness after storage<sup>8</sup> and time to ripening<sup>4</sup>

1. Bower, J.P., et al., 1989. Effect of pre- and post-harvest water stress on the potential for fruit quality defects in avocado (*Persea americana* Mill.). South African Journal of Plant and Soil 6, 219-222.  
2. Everett, K.R., et al., 2008. Avocado lenticel damage: The cause and the effect on fruit quality. Postharvest Biology and Technology 48, 383-390.  
3. Garcia, J.L., et al., 1995. Factors influencing mechanical properties and bruise susceptibility of apples and pears. Journal of Agricultural Engineering Research 61, 11-17.  
4. Hofman, P.J., et al., 2002. Tree yield and fruit mineral concentrations influence 'Hass' avocado fruit quality. Scientia Horticulturae 92, 113-123.  
5. Everett, K.R., et al., 2007. Calcium, fungicide sprays and canopy density influence postharvest rots of avocado. Australasian Plant Pathology 36, 22-31.  
6. Marques, J.R., et al., 2003. Rootstocks influence 'Hass' avocado fruit quality and fruit minerals. Journal of Horticultural Science & Biotechnology 78, 673-679.  
7. Thorp, T., et al., 1997. Survey of fruit mineral concentrations and postharvest quality of New Zealand-grown 'Hass' avocado (*Persea americana* Mill.). NZ J Crop Hort Sci 25, 251-260.  
8. Defilippi, B.G., et al., 2015. Preharvest factors influencing 'Hass' avocado (*Persea americana* Mill.) quality during long term storage. Acta Horticulturae 1071, 137-141.

# What contributes to flesh bruising in avocado?

## Other factors likely to be involved

- Cultivar

*'Fuerte' > 'Lerman' for total phenolic content and PPO activity<sup>1,2</sup>*

*'Hass' > 'Shepard' for peel phenolic concentrations and diversity<sup>3</sup>*

- Rootstock

*'Velvick' > 'Duke 6', 'Duke7' or 'Reed' for fruit calcium concentration and quality, when grafted with 'Hass' scion<sup>4-6</sup>*

1. Golan, A., et al., 1977. Relationship between polyphenols and browning in avocado mesocarp. Comparison between the Fuerte and Lerman cultivars. *Journal of Agricultural and Food Chemistry* 25, 1253-1260.

2. Kahn, V., 1975. Polyphenol oxidase activity and browning of three avocado varieties. *Journal of the Science of Food and Agriculture* 26, 1319-1324.

3. Kosinska, A., et al., 2012. Phenolic compound profiles and antioxidant capacity of *Persea americana* Mill. peels and seeds of two varieties. *Journal of Agricultural and Food Chemistry* 60, 4613-4619.

4. Coates, L.M., et al., 2011. Effects of rootstock on avocado fruit quality – assessment of postharvest disease, major cations and biochemical traits. *Proceedings of the 7th World Avocado Congress, 2011. Cairns, QLD, Australia, 206-214.*

5. Marques, J.R., et al., 2003. Rootstocks influence 'Hass' avocado fruit quality and fruit minerals. *Journal of Horticultural Science & Biotechnology* 78, 673-679.

6. Willingham, S.L., et al., 2006. Effects of rootstock and nitrogen fertiliser on postharvest anthracnose development in Hass avocado. *Australasian Plant Pathology* 35, 619-629.

# Does impact injury also promote body rots?

- Freshly harvested fruit generally do not bruise if dropped
- But... *they appear to be more prone to body rots upon ripening!*
- 30 cm drop height at harvest caused ↑ body rots at soft-ripe stage (*versus no impact at harvest*)
- Response was consistent for 'Hass' fruit harvested from two orchards in different seasons



Impact from 30 cm drop height



No impact

# What can be done to reduce bruising?

- Improve fruit robustness

- Harvest when dry matter is above 23%
- Pass fruit through the supply chain as quickly as possible
- Hold ripened fruit at 5°C
- Ensure that trees receive adequate water
- Avoid harvesting fruit when wet
- Select cultivars that produce fruit with low browning potential
- Select rootstock cultivars that promote Ca accumulation in fruit

More evidence needed

# What can be done to reduce bruising?

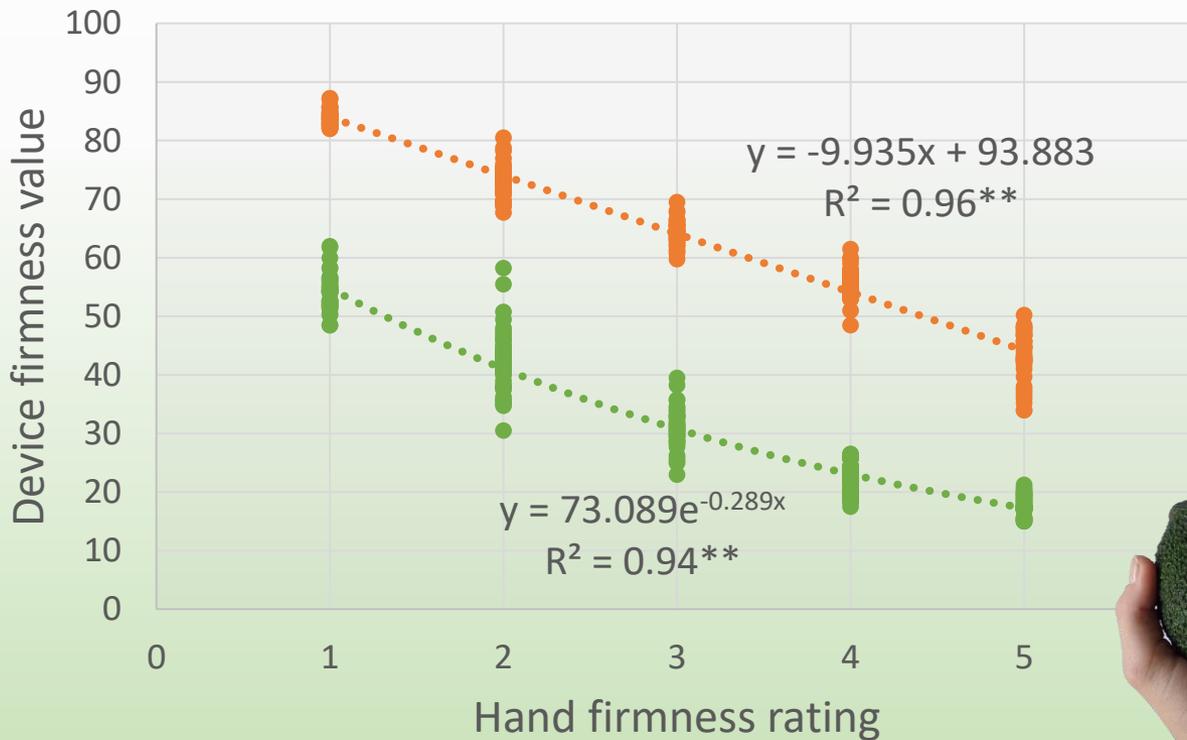
- Limit exposure to injury

- Keep drop heights below 15 cm for hard green mature fruit *(to reduce body rots upon ripening)*
- Keep drop heights below 10 cm for softening fruit
- Handle fruit carefully without dropping or excessive squeezing from firm-ripe stage onwards
- Train retail staff in appropriate handling techniques
- Arrange retail displays into ripeness categories
- Provide point of sale information on fruit selection for ripeness
- Provide shoppers with 'pre-pack' options
- Inform consumers of appropriate in-home handling and storage techniques

More evidence needed

# What can be done to reduce bruising?

- Non-bruising devices for in-store firmness assessment



- Decision aid tool
- FruitFirm



\*\* P < 0.01

# Spreading the message

- Articles in *Talking Avocados*

- New Hort Innovation project to combat flesh bruising in avocado  
Summer 2017 edition
- Factors affecting avocado flesh bruising susceptibility  
Winter 2017 edition, [http://www.avocado.org.au/public-articles/tav28n2\\_bruising/](http://www.avocado.org.au/public-articles/tav28n2_bruising/)
- Best practice handling to reduce flesh bruising  
Summer 2018 edition, [http://www.avocado.org.au/public-articles/tav28n4\\_bruising/](http://www.avocado.org.au/public-articles/tav28n4_bruising/)
- Does impact injury at harvest increase body rots at retail?  
Autumn 2018 edition

- Meetings and workshop

- Avocados Australia 2018 Regional Meetings - Queensland  
Crows Nest, Sunshine Coast, Childers & Mareeba (1 May – 7 June)
- AV15009 Stakeholder Knowledge Sharing Workshop  
Brisbane Markets (15 May 2018)

# Spreading the message

- Poster presentation at TropAg2017 Conference
  - Shopper and consumer contribution to mesocarp bruising in avocado (Persea americana M.) cv. 'Hass' fruit and a prototype decision aid tool for in-store firmness assessment*
  - Brisbane, 20-22 November
  - Conference attendance: 720 delegates from 46 countries
- YouTube video
  - In production, due for release mid-2018*

**Mesocarp bruising in avocado (*Persea americana* M.) cv. 'Hass' fruit post-ripener and a prototype tool for firmness assessment in retail stores**

D. Joyce<sup>1,2</sup>, M. Mazhar<sup>3</sup>, A. Muriro<sup>3</sup>, N. Tuttle<sup>3</sup>, P. Gapes<sup>3</sup>, X. Qiu<sup>3</sup>, P. Hofman<sup>3</sup>, R. Collins<sup>3</sup>, M. Perkins<sup>3</sup>

<sup>1</sup>Department of Agriculture and Fisheries, Ecosciences Precinct, PO Box 267, Brisbane, Queensland 4560, Australia. <sup>2</sup>The University of Queensland, School of Agriculture & Food Sciences, Gatton, Queensland 4343, Australia. <sup>3</sup>School of Rehabilitation Sciences, Griffith University, Gold Coast Campus, Queensland 4222, Australia. <sup>4</sup>Health Data Systems, PO Box 20, Underwood, Queensland 4119, Australia. <sup>5</sup>Department of Agriculture and Fisheries, PO Box 5083, SCMG Hamבור, Queensland 4560, Australia.

**Background**  
Avocado is consumed worldwide for its flavor and health benefits, with the cultivar 'Hass' dominating the market. However, studies have shown that consumers are not entirely satisfied with the quality of avocado fruit being marketed to them<sup>1,2</sup>. Mesocarp bruising (Figure 1), in particular, has been identified as a major quality issue.

**Project aims**

- Quantify mesocarp bruising in 'Hass' avocado fruit through the supply chain; and
- Identify the major contributors to avocado mesocarp bruising.

**Methodology**  
**Mesocarp bruising through the supply chain**  
'Hass' avocado fruit harvested and packed at Childers, Queensland, Australia, were sampled (n=25 fruit) at each of seven stages in the supply chain between arrival at the packing facility in Brisbane (Queensland, Australia) and the consumer's home. Fruit were held at 20°C for 48 h after collection and destructively assessed for bruise volume.

**Shopper contribution to mesocarp bruising**  
Single 'Hass' avocado fruit at firm-ripe stage were assessed for bruising in response to:  
• Single handling by a shopper in a retail supermarket (n=60);  
• Multiple handling by shoppers during a 6-h on display in a retail supermarket (n=40);  
• Multiple handling by 20 shoppers asked to assess fruit firmness according to their normal practice (n=20).  
For each experiment, a separate set of fruit (n=20) were retained as an un-handled control. Discreet observations of avocado handling by random shoppers (n=257) were also made throughout the study period.

**Consumer contribution to mesocarp bruising**  
Bruise-free, firm-ripe 'Hass' avocado fruit were provided to consumers after the check-out period at a supermarket retail store. The fruit (n=2) were collected back from consumer's homes after 2 days. Bruising was compared with that of un-handled control fruit (n=10).

**Compression forces leading to mesocarp bruising**  
A single-force sensor P30 (Intertek Electronics, Campbell, CA, United States) placed between the thumb and the fruit used to quantify compression force applied to firm-ripe 'Hass' avocado fruit by shoppers (n=25). Laboratory-based fruit firmness assessments were also conducted on fruit (n=20) subjected to around 10, 20 or 30 N thumb compression at either soft-ripe or firm-ripe stage. Fruit were assessed for bruise volume and bruise intensity (hue angle and chroma) using a chroma meter (CR 400; Minolta Ltd, Osaka, Japan).

**Decision aid tool (DAT) for avocado fruit firmness**  
In light of findings from the above experiments, a prototype DAT for objective assessment of fruit firmness via a force sensing resistor was developed for use in retail stores. Shopper attitudes toward the DAT were determined through a survey conducted in three supermarket retail stores in South Queensland. Thirty participants at each store were asked to assess the firmness of a silicone avocado replica by hand and then with the DAT. Participants were asked to complete a questionnaire in which they rated their experience with the DAT.

**Results**

- Bruise severity was negligible until fruit reached the retail store and the consumer's home (Figure 2).
- Fruit handled once by a single shopper exhibited bruise volumes ranging from 0.6 to 2.0 mL (Figure 3A) and had a higher mean bruise volume (1.0 mL) than un-handled fruit (0.1 mL).
- Multiple (Figure 3B) and random (Figure 3C) handling of fruit by shoppers also produced significantly higher mean bruise volumes (22.4 and 2.9 mL, respectively) compared to those found in un-handled control fruit (0.2 mL).
- In-store observations indicated that shoppers spend an average of 5 to 8 s at the avocado display and handle around twice as many fruit as they purchase (Table 1).
- Consumer handling produced bruise volumes ranging from 0 to 7 mL (Figure 3D) and a higher mean bruise volume (0.7 mL) than that observed in un-handled control fruit (0.2 mL).
- Shoppers applied between 2.9 N and 28.6 N compression force to fruit during firmness assessment, producing subsequent bruise volumes ranging from 0.1 to 1.2 mL.
- 10 N compression force applied to firm-ripe fruit was sufficient to cause bruising and bruise intensity increased with increasing compression force (Table 2).
- About 97% of shoppers who used the prototype DAT (Figure 4) found it helpful in assessing avocado fruit firmness (Figure 5).

**Table 1. Avocado avocado fruit handling practices observed in shoppers of differing age and gender.**

| Estimated age (years) | Gender      | Time spent (s) | No. fruit handled | No. fruit purchased |
|-----------------------|-------------|----------------|-------------------|---------------------|
| <30                   | Female (31) | 6.37           | 3.22              | 1.27                |
|                       | Male (24)   | 6.68           | 3.09              | 1.12                |
| 30-50                 | Female (26) | 6.03           | 3.47              | 1.38                |
|                       | Male (18)   | 7.56           | 3.56              | 1.04                |
| >50                   | Female (15) | 6.80           | 3.42              | 1.40                |
|                       | Male (17)   | 6.67           | 2.47              | 1.00                |

**Table 2. Mesocarp bruise intensity (hue angle and chroma) and severity in 'Hass' avocado fruit (n=20) subjected to hand compression at firm-ripe or soft-ripe stage, as measured with a force sensor (n=20). Means within a column that do not share a letter are significantly different (P < 0.05) according to Tukey's HSD test.**

| Stage     | Force (N) | Bruise volume (mL) | Bruise intensity (a*) |
|-----------|-----------|--------------------|-----------------------|
| Firm-ripe | 0         | 0.04±0.09          | 26.1±2.24             |
|           | 10.0±0.4  | 0.03±0.12          | 33.1±5.49             |
|           | 20.0±0.9  | 0.7±0.65           | 27.6±4.9              |
|           | 30.0±0.6  | 0.2±0.11           | 25.3±2.24             |
|           | 10.0±0.4  | 0.03±0.10          | 33.7±1.74             |
|           | 20.0±0.4  | 0.04±0.04          | 34.8±1.59             |
| Soft-ripe | 21.1±0.9  | 0.1±0.20           | 30.3±0.61             |
|           | 20.0±0.8  | 0.5±0.26           | 25.9±2.68             |
|           | 10.0±0.4  | 0.04±0.04          | 34.8±1.59             |

**Discussion and conclusions**  
Mesocarp bruising in 'Hass' avocado fruit is most prevalent at the retail and consumer stages of the supply chain (Figure 2). This study has proven that shoppers and consumers are major contributors to bruising (Figure 3). Compression force applied by shoppers in many cases exceeds the 10 N known to cause bruising (Table 2). Hence, an in-store DAT that allows shoppers to assess avocado fruit firmness using slight (<10 N) compression force is likely to result in lower incidence and severity of mesocarp bruising at retail. Most shoppers responded positively to the prototype DAT developed in this study (Figure 5), indicating that such technology would be readily adopted by shoppers if made available. Knowledge generated by this study may be used to develop educational guides for firmness assessment. Avocado fruit quality at retail is likely to improve as shoppers and consumers are made aware of their role in mesocarp bruising and are provided access to DATs that limit damage to the fruit.

**Figure 1. Responses of shoppers to the question, 'In comparison with squeezing with your bare hand, how helpful do you think that the prototype DAT was to your assessing of avocado fruit firmness?'**

| Response       | Proportion of respondents (%) |
|----------------|-------------------------------|
| Very helpful   | 100                           |
| Helpful        | 100                           |
| Neutral        | 100                           |
| Unhelpful      | 100                           |
| Very unhelpful | 100                           |

# Where to next?

- **Current project** (June – October 2018)

- Monitor fruit quality through two prominent supply chains

*Queensland → Victoria*

*Western Australia → Victoria*



- Simulate supply chain conditions in the laboratory

*best practice vs poor practice → final fruit quality*

# Where to next?

- Concept note submitted to Hort Innovation for future research into:
  - Orchard management practices for effects on bruise susceptibility and postharvest disease expression in ripe fruit at retail level
  - Development of decision aid tools to optimize orchard management and fruit robustness from farm to consumer

*There is currently no published research on avocado bruise susceptibility in response to tree vigour, crop load and nutrition!*

# Concluding remarks

Based on current knowledge, there are changes in harvesting and handling practices that can be made now to reduce flesh bruising

- Harvest above 23% dry matter and when fruit are not wet
- Minimise drop heights – handle ripe fruit “like eggs”
- Maintain fruit temperature of 5°C (except when ripening)
- Pass fruit through the supply chain as quickly as possible

*But...*

There are many other factors likely to affect flesh bruising at retail

We need to confirm and quantify their contribution...

...and estimate the economic consequences to industry!

# Acknowledgements



AV15009 is funded by Hort Innovation, using the Hort Innovation Avocado research and development levy, co-investment from the Queensland Department of Agriculture and Fisheries, the University of Queensland, Avocados Australia Ltd and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

The Project Team also wishes to acknowledge the contributions made by Murray Brothers, Farmgate 1411, Redbank Plantation, Brett Jahnke and technical staff and students of the UQ School of Agriculture and Food Sciences.