Horticulture Innovation - Australian Citrus Postharvest Science Program (CT15010)

Focus - Development of a postharvest program for ultra-low chemical residues

Aims
• assess chemistry and other emerging technologies to address postharvest issues
• facilitate the adoption postharvest program with presentations across Australia
• keep industry informed with targeted communications using online platforms and other channels
• identify options to engage postharvest services on a fee-for-service basis for advice specific to their business
Postharvest decay control

Postharvest decay control must use a range of complementary strategies:
+ correct harvesting and handling
+ shed hygiene
+ correct use of sanitisers
+ use of fungicides
+ temperature management
+ monitoring inoculum levels and fungicide resistance
Fungicide resistance survey

Survey of resistance to postharvest fungicides in representative packingsheds across Australia from May to September 2018 (follow on from previous June/July 2017)

- New South Wales
- Queensland
- South Australia
- Victoria
- Western Australia

Test resistance to common postharvest fungicides (TBZ, imazalil and fludioxonil)

→ 3 locations in shed: (1) start of the line, (2) end of the line and (3) coolroom
## 2018 Fungicide sanitation and fungicide resistance survey results

### Follow-up after sanitation and hygiene improvements

<table>
<thead>
<tr>
<th>Shed</th>
<th>Time</th>
<th>Untreated</th>
<th>TBZ</th>
<th>Imazalil</th>
<th>Fludioxonil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>S E C T</td>
<td>S E C T</td>
<td>S E C T</td>
<td>S E C T</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>3 3 4 10</td>
<td>1 4 3 8</td>
<td>1 1 1 3</td>
<td>1 1 1 3</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>3 1 1 5</td>
<td>1 1 1 3</td>
<td>1 1 1 3</td>
<td>1 1 1 3</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>4 4 2 10</td>
<td>4 4 3 11</td>
<td>1 1 1 3</td>
<td>1 1 1 3</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>4 3 1 8</td>
<td>4 4 1 9</td>
<td>1 1 1 3</td>
<td>1 1 1 3</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>4 3 2 9</td>
<td>4 4 4 12</td>
<td>1 1 1 3</td>
<td>1 1 1 3</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>1 1 1 3</td>
<td>2 2 3 7</td>
<td>1 1 1 3</td>
<td>1 1 1 3</td>
</tr>
</tbody>
</table>
Reducing fungicide resistance

Management of fungicide resistance requires an integrated approach:

1. Optimise fruit health
2. Use best hygiene practices
3. Optimise fungicide use
4. Optimise fungicide efficacy
5. Monitor fungicide resistance
Reducing fungicide resistance

3. Optimise fungicide use

→ rotate different fungicides with different actions

• Understand the class of fungicide you are using and limit the total number of fungicide applications of any one class.

= the continued use of the same fungicide class can cause selection pressures resulting in resistance

• Use rotations and mixtures or pre-mixtures whenever possible before resistance selection occurs

• Use the label rate for each fungicide - lower rates of fungicide can select for less sensitive spores in the population
### Reducing fungicide resistance

<table>
<thead>
<tr>
<th>Compound</th>
<th>Brand(s)</th>
<th>Group(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thiabendazole (TBZ)</strong></td>
<td>Vorlon®, Tecto®</td>
<td>GROUP 1 FUNGICIDE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Benzimidazole Group <em>(activity also on Stem End Rot, Phomopsis citri)</em></td>
</tr>
<tr>
<td><strong>Imazalil</strong></td>
<td>Magnate®, Fungaflor®</td>
<td>GROUP 3 FUNGICIDE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMI (Demethylation Inhibitors) <em>(Imidazole)</em></td>
</tr>
<tr>
<td><strong>Imazalil + Pyrimthanil</strong></td>
<td>Philabuster®</td>
<td>GROUP 3 + 9 FUNGICIDE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMI and Anilinopyrimidine Group</td>
</tr>
<tr>
<td><strong>Fludioxonil</strong></td>
<td>Scholar®</td>
<td>GROUP 12 FUNGICIDE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phenylpyrrole Group <em>(activity also Diplodia Stem End Rot)</em></td>
</tr>
<tr>
<td><strong>Propiconazole + Fludioxonil</strong></td>
<td>Chairman®</td>
<td>GROUP 3 + 12 FUNGICIDE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMI and Phenylpyrrole Group</td>
</tr>
</tbody>
</table>

Preventol® ON Fungicide *(controls blue mould only)* *(sodium ortho-phenylphenate)*
Fungicide best practice application

Effect of time of fungicide dipping time on decay development

Chairman™ = fludioxonil + propiconazole

Australian Citrus Postharvest Science Program (CT15010)
Fungicide best practice application

Effect of time of fungicide dipping time on decay development

Green mould

- **Control**
- **Imazalil**
- **Fludioxonil**
- **Chairman**
- **Philabuster**

**Chairman™** = fludioxonil + propiconazole

**Philabuster™** = imazalil + pyrimethanil

<table>
<thead>
<tr>
<th>Time before dipping (hours)</th>
<th>Control</th>
<th>Imazalil</th>
<th>Fludioxonil</th>
<th>Chairman</th>
<th>Philabuster</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 hours</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>12 hours</td>
<td>90%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>24 hours</td>
<td>80%</td>
<td>20%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>48 hours</td>
<td>70%</td>
<td>30%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>72 hours</td>
<td>60%</td>
<td>40%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Fungicide best practice application

Effect of time of fungicide dipping time on decay development

Blue mould

![Bar chart showing the effect of time on blue mould infection with different fungicides.]

- **Control**
- **Imazalil**
- **Fludioxonil**
- **Chairman**
- **Philabuster**

**Chairman™** = fludioxonil + propiconazole

**Philabuster™** = imazalil + pyrimethanil

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**Australian Citrus Postharvest Science Program (CT15010)**

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Fungicide best practice application

Effect of time of sanitisers and fungicide dipping time on decay development

**Propirly™** = propiconazole + pyrimethanil

**Philabuster™** = imazalil + pyrimethanil

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Australian Citrus Postharvest Science Program (CT15010)
Non-chemical decay control

Effect of hot water on spore mortality

Green mould (sensitive strain)

Blue mould (sensitive strain)

Green mould (TBZ resistant strain)

Sour rot

Australian Citrus Postharvest Science Program (CT15010)
Non-chemical decay control

Effect of hot water on decay development in oranges

Green mould

Blue mould

% Infection with green mould

% Infection with blue mould

Treatment Temperature (°C)

Australian Citrus Postharvest Science Program (CT15010)
Alternative postharvest treatments

Development and assessment of new citrus fruit coatings

Bahareh Saberi, John Golding and Penta Pristijono – see poster

Alternative edible coatings (eg starch and guar gum based coatings) assessed during storage and shelf life

Pea starch and guar gum (PSGG)-based edible coatings could be a beneficial substitute to commercial waxes
Non-chemical decay control

Low oxygen and low pressure on decay development in oranges

John Archer, Penta Pristijono, Quan Vuong, Lluis Palou, John Golding

Low oxygen treatment (1% \(O_2\)) + low pressure (7 kPa)

Both treatments reduced the growth of green mould
Reducing fungicide resistance

2. Use best hygiene practices

→ good postharvest hygiene

Reduce numbers of decay-causing spores in the shed, cool room and on the fruit = reduced risks

• Remove all culled and especially decaying fruit from the shed
• Regular sanitation of equipment (including picking bins), cool rooms and packing line
• Ideal to have a separate area of receivals of fruit to the packing line
• Good shed hygiene
Assessing new sanitation methods

ChillSafe® is a sachet which slowly releases hydrogen peroxide gas into the coolroom

Hydrogen peroxide is an unstable gas which kills mould spores (and also oxidises ethylene - *degreening)

https://coolsan.com.au
Assessing new sanitation methods

ChillSafe® - impact on *Penicillium* spores

Treatment of decay spores

+ ‘ChillSafe®’ active ingredient in sealed container

*Penicillium* decay spores
Assessing new sanitation methods

+ ChillSafe® a.i.

No treatment

active ingredient (a.i.)
(6 x 10⁴ spores were exposed to a.i. for 4 days at 20°C )

- green mould
- blue mould
- green mould
- blue mould

Australian Citrus Postharvest Science Program (CT15010)
Assessing new sanitation methods

Blue mould growth on agar plate

active ingredient (a.i.)
(6 x 10^4 spores were exposed to a.i. for 14 days at 20°C)

+ ChillSafe® a.i.  No treatment

+ 14 days
Assessing new sanitation methods

Green mould growth on agar plate

active ingredient (a.i.)
(6 x 10^4 spores were exposed to a.i. for 14 days at 20°C)

+ ChillSafe® a.i.  No treatment

→ Coolrooms…

Australian Citrus Postharvest Science Program (CT15010)
Managing chemical residues

Effect of postharvest washing on dithiocarbamate residues in lemons

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Concentration (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cold chlorine</td>
<td>0.643 a</td>
</tr>
<tr>
<td>hot PAA</td>
<td>0.712 a</td>
</tr>
<tr>
<td>hot water only</td>
<td>0.775 a</td>
</tr>
<tr>
<td>cold water only</td>
<td>0.810 a</td>
</tr>
<tr>
<td>cold PAA</td>
<td>0.817 a</td>
</tr>
<tr>
<td>hot PAA – stored</td>
<td>1.027 a</td>
</tr>
<tr>
<td><strong>no treatment</strong></td>
<td><strong>2.933 b</strong></td>
</tr>
</tbody>
</table>

Postharvest washing can reduce dithiocarbamate residues in lemons. **However ALL efforts should be undertaken to reduce the risk of chemical contamination** - see poster.

Australian Citrus Postharvest Science Program (CT15010)
Long term storage

Effect of ethylene in storage coolroom on fruit quality
- Nasiru Alhassan see poster

Effect of storage temperatures and ethylene levels on button browning of ‘Afourer’ mandarins after 4 weeks storage

<table>
<thead>
<tr>
<th>Ethylene (µL.L⁻¹)</th>
<th>Storage temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5°C</td>
</tr>
<tr>
<td>&lt;0.001</td>
<td>2.6</td>
</tr>
<tr>
<td>0.01</td>
<td>2.8</td>
</tr>
<tr>
<td>0.1</td>
<td>2.9</td>
</tr>
<tr>
<td>1.0</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Button score rating.
2 = slightly yellow,
3 = moderate yellow,
4 = totally yellow,
5 = brown

→ Low temperature and low ethylene maintain fruit quality during long term storage

Supervision – Penta Pristijono, Prof. Ron Wills, Michael Bowyer, John Golding

Australian Citrus Postharvest Science Program (CT15010)
Long term storage

Maintaining lime fruit quality during storage
- Penta Pristijono and John Golding – see poster

Effect of UV-C treatment on lime fruit quality

UV-C light = 100-280 nm

UV-C treatment delayed yellowing and no effect on other quality

Effect of UV-C treatment on lime fruit quality

Overall acceptability

2 weeks

3 weeks

4 weeks

Australian Citrus Postharvest Science Program (CT15010)
Long term storage

Maintaining lime fruit quality during storage
- Penta Pristijono and John Golding – see poster

Effect of UV-C treatment and 1-MCP on lime fruit quality

1-MCP ‘SmartFresh®’ stops ethylene action

UV-C and 1-MCP further maintained quality (yellowing) and no effect on other quality

4 weeks at 20C
Adding value
Adding value to citrus pomace
Kostas Papoutsis. University of Newcastle

Optimise extraction and preparation methods
- see poster

Spore germination

Fungus growth

Australian Citrus Postharvest Science Program (CT15010)
Market access

Irradiation

Benefits
- important tool in market access toolbox efficacious and accepted
- short term treatment with high volumes and speed
- no cold treatment – no potential chilling injury
- no packaging issues
- no chemicals

Issues
- not accepted by many importing countries, but still some good markets in SE Asia (such as Vietnam, Indonesia)
  But perhaps new markets coming
- potential consumer acceptance issues*
- potential fruit quality issues*
- limitation of treatment facilities – Steritech in Brisbane

* (and Melbourne - 2019)

Australian Citrus Postharvest Science Program (CT15010)
Market access

Irradiation
Growing markets and treatment

Australian grapes to Vietnam
Y1  800 pallets
Y2 1200 pallets
Y3 1800 pallets
Y4 tracking for + 2000 pallets
All air freight and all trucked to Brisbane

Citrus
2018 - 150 pallets for Vietnam (double 2017 volumes)
Approximately 50% mandarins + 50% oranges (2017 - 70% mandarins, 30% oranges)

Data from Steritech – Ben Reilly (Feb 2019)
Market access

Irradiation – Review of potential fruit quality issues

No Chilling Injury

Few consistent negative effects of irradiation

Some reports of surface damage (such as pitting) can occur in some types of different citrus

- In literature

Lane Late navel oranges (McDonald et al., 2013)

Chandler pummelo (Jain et al., 2017)

Kishu mandarins (Ornelas-Paz et al., 2017)
Market access

Irradiation – Commercial treatment

Steritech

2018 - treated 150 pallets citrus

Data from Steritech – Ben Reilly (Feb 2019)

Australian Citrus Postharvest Science Program (CT15010)
Chilling Injury

Storage disorder following low temperature storage

→ shallow pitting of the peel, browning of the albedo

Symptoms not always develop, but severity = storage temperature x time (more chilling with lower storage temperatures and treatment times)

Injury to the peel occurs at low temperature but symptoms often appear after fruit is removed from storage

*Cause and prediction of chilling injury is not known*
Market access

Chilling Injury – Preharvest factors

- **citrus type and cultivar**
  
  *In general*: grapefruit > lemon / limes > oranges / mandarins

  Navel oranges
  ‘Navelate’ and ‘Roberts’ > ‘Thomson’ > ‘Navelina’

- **orchard conditions**
  
  Preharvest orchard temperatures, harvest times, growing locations etc.

  Earlier and later harvest fruit > mid-season fruit
  = but this does not always hold in different seasons and growing conditions

  → *we still do not know what causes chilling injury and its contributing factors*

Katina Lindhout (2007)
Market access

Postharvest treatments to reduce chilling injury

**Temperature treatments.** Short term high temperature treatments / conditioning (hot water dips, hot water brushing, curing or conditioning with hot humid air)

**Fungicides.** Thiabendazole (TBZ) and warm TBZ (40°C)

**Waxes.** Different outcomes with different wax and fruit types

**Modified atmospheres.** MA and high relative humidity

**Others…** Plant growth regulators such as jasmonic acid and salicylic acid
Market access

Postharvest treatments to reduce chilling injury

Effects of ethylene levels on chilling injury after 1°C storage and shelf life (5 days at 20°C) in Navel oranges

<table>
<thead>
<tr>
<th>Ethylene level (ppm)</th>
<th>1 week</th>
<th>3 weeks</th>
<th>5 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.001</td>
<td>0.9</td>
<td>1.8</td>
<td>3.0</td>
</tr>
<tr>
<td>0.1</td>
<td>0.6</td>
<td>1.1</td>
<td>2.0</td>
</tr>
<tr>
<td>1</td>
<td>0.3</td>
<td>0.7</td>
<td>1.2</td>
</tr>
</tbody>
</table>

+ ethylene reduced chilling injury

Nasiru Alhassan. University of Newcastle

Australian Citrus Postharvest Science Program (CT15010)
Collaboration and training

University of Newcastle

Current students:
- Hort Innovation PhD training - John Archer – *Alternative decay control methods*
- Mizan Rahman – *Utilising citrus pomace to control postharvest decay*
- Nasiru Alhassan - *Maintaining the quality of citrus fruits for long term storage*

University of Newcastle staff – Prof. Ron Wills, Dr. Penta Pristijono, Dr. Michael Bowyer, Dr. Quan Vuong

Previous PhD students with citrus-related projects:
- Kostas Papoutsis, Bahareh Saberi

Institut Valencià d’Investigacions Agràries (IVIA) (Spain)
- Prof. Lluis Palou

*Australian Citrus Postharvest Science Program (CT15010)*
More information

• Exposure to low ethylene and storage temperatures delays button (calyx) aging and maintains ‘Afourer’ mandarins and Navel oranges quality

• Evaluating the effects of plastic film packaging on postharvest quality of Navel oranges

• Development and assessment of new citrus fruit coatings

• Effects of temperature and time on postharvest fungicide efficacy

• Alternative decay control strategies using citrus essential oils

• Effect of postharvest washing on residues of preharvest sprays in lemons
• Antifungal activity of citrus by-product aqueous extracts against *Alternaria*

• Assessment of postharvest UV-C treatments to maintain quality of limes

• Combined postharvest treatments of UV-C and 1-methylcyclopropene (1-MCP) to maintain the quality of limes

• Effect of postharvest UV-C light on postharvest decay and Navel orange fruit quality

• Evaluating the effects of low pressure and low oxygen on the postharvest growth of green mould
More information

Regular articles in Australian Citrus News

- ‘The Essentials of Degreening. Part 1’
- ‘Degreening for optimal results. Degreening Part 2’
- ‘Postharvest decay control – fungicides and sanitisers’
- ‘Preventing postharvest fungicide resistance’
- ‘Packinghouse Hygiene - Sanitation and Food Safety’
- ‘Maintaining lime fruit quality during storage’
- ‘Food safety is everyone’s responsibility’
- ‘Management change can reduce fruit decay’
More information
On-line YouTube video clips

Degreening citrus
Promoting colour development in mature citrus

www.citrusaustralia.com.au

Australian Citrus Postharvest Science Program (CT15010)
More information

Regular updates in:

Australian Citrus News
Citrus E-news
You tube clips
– degreening citrus

Packer Newsletter

NSW DPI – Citrus Connect

Workshops

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

Hort Innovation and Australian citrus growers and packers for their assistance and co-operation

Project Reference Committee. Nathan Hancock (Citrus Australia), Allen Jenkin (Ironbark Citrus), Ben Cant (Costa Group), Domenic Mercuri (Pacific Fresh) and Ashley Zamek (Horticulture Innovation)

NSW Department of Primary Industries co-investing in this Project. John Archer, Dr Shashi Satyan, Mark Bullot, Dr Len Tesoriero, David Cruickshank, Christine Cruickshank, Lorraine Spohr, Anne Harris, Carly Murray, Fiona Lidbetter, Steven Falivene, Andrew Creek, Mark Hickey, Dr Shane Hetherington

The University of Newcastle. Staff – Prof Ron Wills, Dr Penta Pristijono, Dr Michael Bowyer, Dr Quan Vuong, Dr Yongxin Li. Students - Mohammad Rahman, Nasiru Alhassan, Dr Kostas Papoutsis, Dr Bahareh Saberi

Institut Valencià d’Investigacions Agràries (IVIA) (Spain) - Prof Lluis Palou

This project was also supported by University of Newcastle led ARC Food & Beverage Supply Chain Optimisation Industrial Transformation Training Centre (Dr Penta Pristijono)

Support from Citrus Australia, Bronwyn Walsh (WA Citrus), E.E. Muir & Sons Pty Ltd, Colin Campbell (Chemicals) Pty. Ltd., Landmark

Visiting students from France. Malorie Dien, Martin Emonet, Fabien Huteau, Laure Houizot, Typhaine Haurogné, Quentin Gallien, Loic Vuillemenot, Clemence Lerat and Julien Thomas

Sydney University students. Bennie Feng, Sandra Joy Evangelista, Qing Guo, Ju Hyuck

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