University of South Australia

## Bio – Michael Coates

Michael Coates is a PhD student currently funded through an Australian Postgraduate Award Scholarship with additional funds provided by Horticulture Innovation Australia (HIA) using the Australian almond industry levy, voluntary contributions from industry and matched funds from the Australian Government. He is part of the agricultural machine research and design centre (AMRCD) which is developing novel methods of almond harvesting and processing aimed at addressing the environmental and safety concerns of an ever expanding industry. The centre is currently examining the impact of early "green" harvest and shake and catch systems, as well as on-farm hulling and mechanical drying. AMRDC has a 30 year history of producing agricultural solutions for cereal grain farming, dried fruit and wine grape production.

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# Innovative drying and harvesting

Michael Coates

University of South Australia

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# AMRDC

Agricultural Machine Research and Design Centre

Michael Coates

Professor John Fielke

Dr Maryam Shirmohammadi

University of South Australia

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# Australian Almonds

## Not a true Mediterranean climate

- We don't have the best  soil
- Get rain in the late season cultivars
- Most of our crop is transported to 7 huller and shellers
- Stockpile at the farm

**We face a number of challenges that keep the innovative juices flowing.**

Ross Skinner (CEO) - The Advanced processing of Almonds (Advanced Harvesting)

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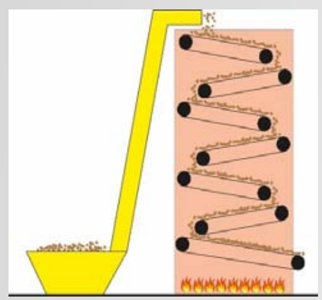
# Advanced Harvest

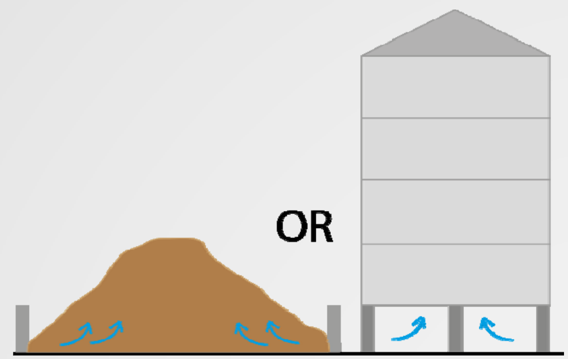
## What is advanced harvesting?

1. Shake and catch (fruit not hitting the ground)
2. Earlier Harvest times
3. On-farm hulling (keeping hulls on farm)
4. Mechanical dehydration
5. Aerated on-farm storage

Shake and Catch



Dehydration




Aerated Storage

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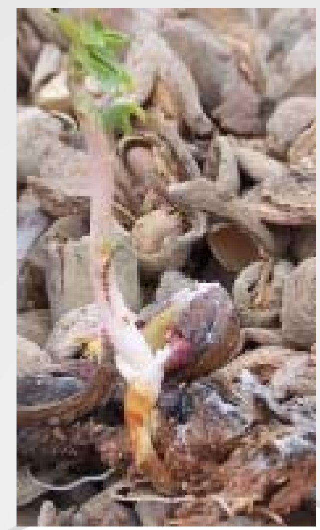
# Benefits

- Harvesting independent of the weather
  - Avoids fruit damage from rain events
- Reduces mould / bacteria exposure
- Reduces pest infestation
- Easier to remove hull whilst green
  - Retain hulls of farm (nutrient value)
  - Reduced storage and transport costs
- Eliminate sweep and pickup passes
- Significant dust reduction



http://www.abc.net.au/news/2015-04-29/rain-allows-for-second-almond-harvest/6427720
http://honeywithoutflowers.blogspot.com.au/2012/10/harvest-fog.html

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# Advanced Harvest

There was a number of questions:

- How early can we harvest?
- Does mechanical drying effect the kernel?
- Are there consequences for drying high moisture fruit in bulk?
- Is it practical to aerate stock piles?

# How early can we harvest?

Benefits – Pest control

Concerns:

- Dry weight
- Nutrient Load
- Kernel colour

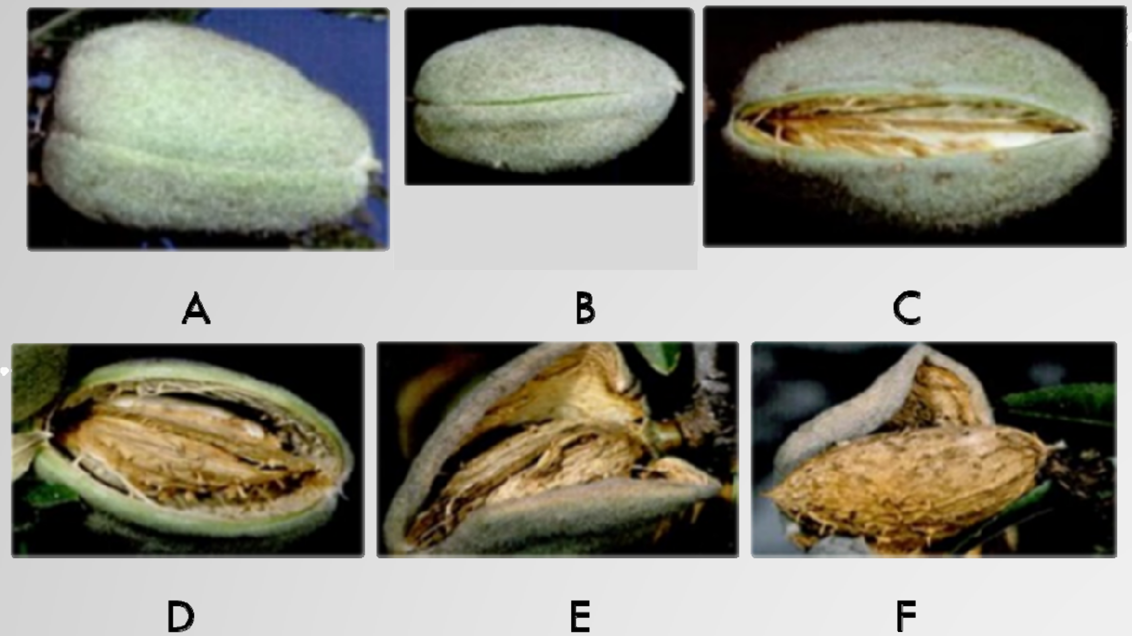
2015 - Arbuckle, CA
2016 - Walker Flat, South Australia

# When is the frut ready?

Days after full bloom (DAFB)

Growing Degree Days (GDD)

http://ucanr.edu/sites/Nut_Crops/newsletters/From_the_Shell47971.pdf




IPM Hull Split categories (Discrete method of identifying fruit)

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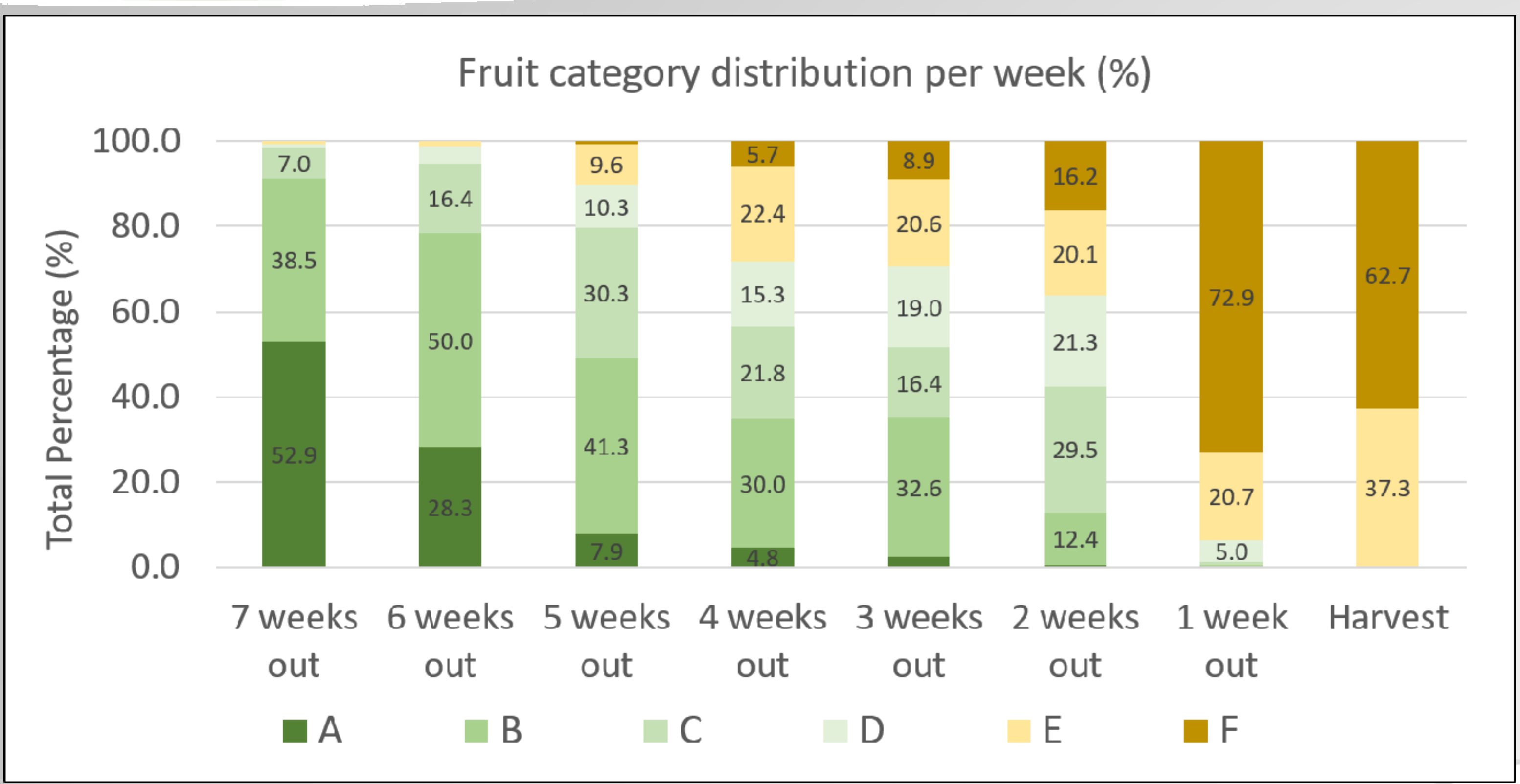
# Estimated distribution

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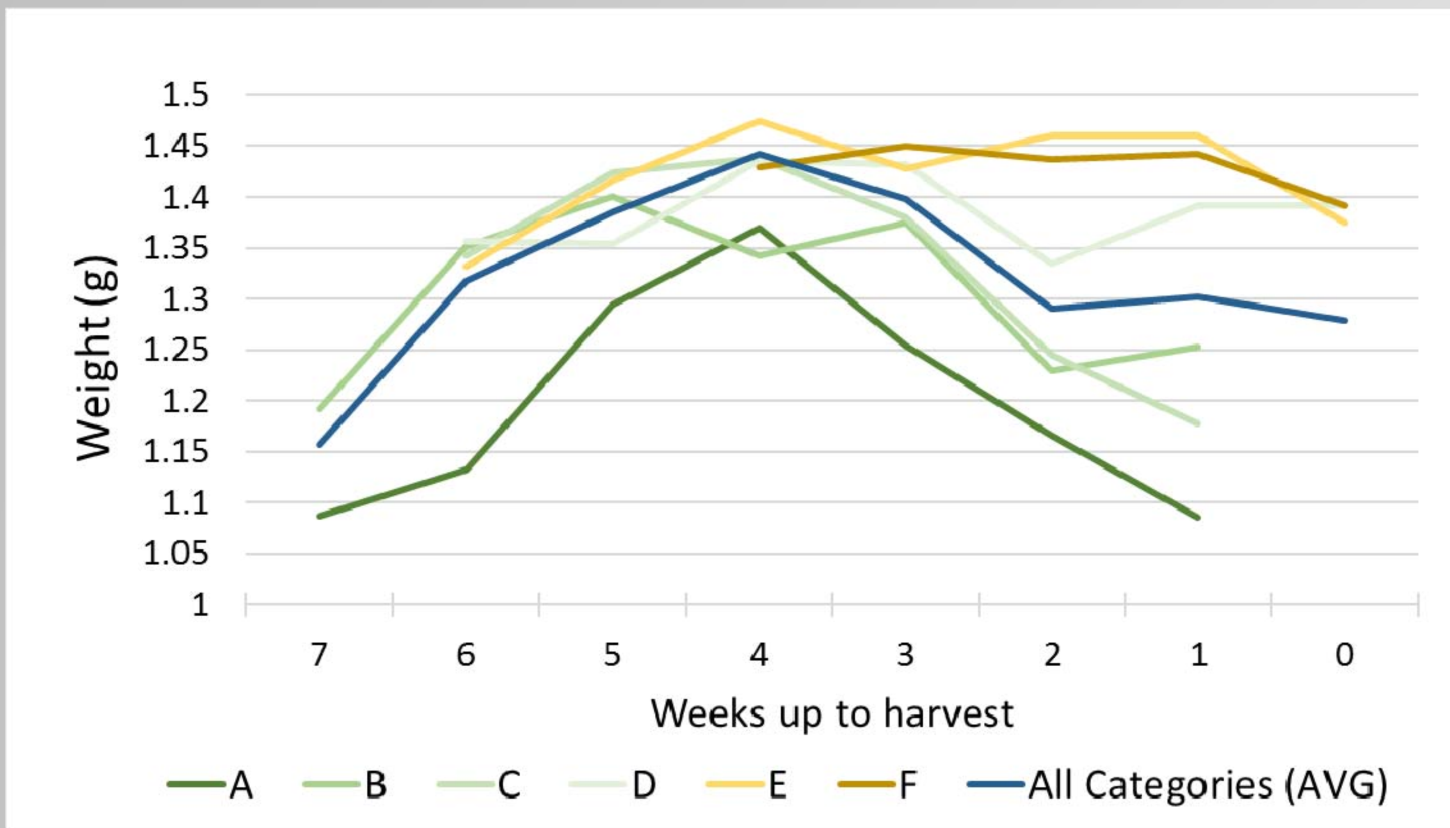
# Dry weight

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# Nutrition profile

| Nutrient Composition of Early Harvested Almonds (Dry Weight Basis) | | | | | | NP Natural Variability (As Is Basis) |
|---|---|---|---|---|---|---|
| Nutrient | 4 week | 3 week | 2 week | 1 week | Harvest | |
| Ash | 2.8 ± 0.07 | 2.8 ± 0.06 | 2.8 ± 0.06 | 2.8 ± 0.03 | 2.8 ± 0.08 | 3.1 ± 0.3 |
| SFAs | 3.6 ± 0.09 | 3.6 ± 0.02 | 3.7 ± 0.08 | 3.7 ± 0.12 | 3.8 ± 0.06 | 3.8 ± 0.1 |
| PUFAs | 11.3 ± 0.32 | 11.2 ± 0.60 | 11.6 ± 0.36 | 11.5 ± 0.43 | 11.6 ± 0.37 | 12.4 ± 1.4 |
| Protein | 20.6 ± 0.24 | 20.4 ± 0.14 | 19.8 ± 0.63 | 20.0 ± 0.53 | 20.1 ± 0.71 | 20.2 ± 0.9 |
| Vit. E | -- | 25.8 ± 0.65 | 26.0 ± 0.66 | 25.7 ± 1.46 | 26.0 ± 0.81 | 26.0 ± 1.9 |
| MUFAs | 33.4 ± 2.18 | 33.7 ± 1.52 | 34.5 ± 0.62 | 34.5 ± 0.61 | 34.3 ± 1.60 | 31.3 ± 2.5 |
| Fatty Acids | 50.5 ± 2.59 | 50.7 ± 2.06 | 52.2 ± 0.27 | 52.0 ± 0.94 | 51.9 ± 1.53 | -- |
| Fat | 51.6 ± 2.50 | 52.5 ± 1.61 | 53.2 ± 0.50 | 53.2 ± 0.77 | 53.9 ± 1.96 | 49.6 ± 1.9 |

Analysis by Guangwei Huang

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# Colour


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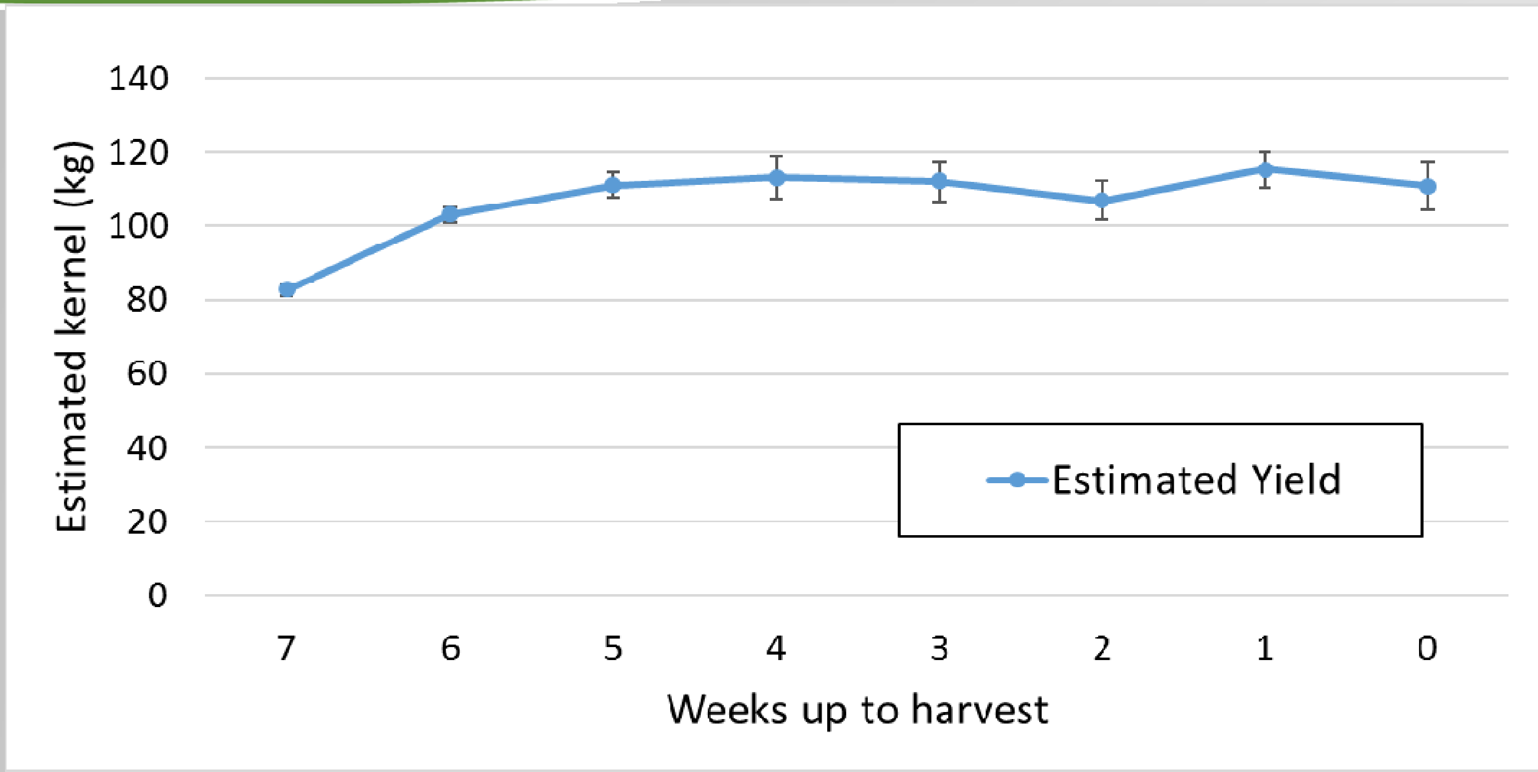
# Estimated yield




Based on 8000 kernels

# Tree Damage

7 weeks out

6 weeks out

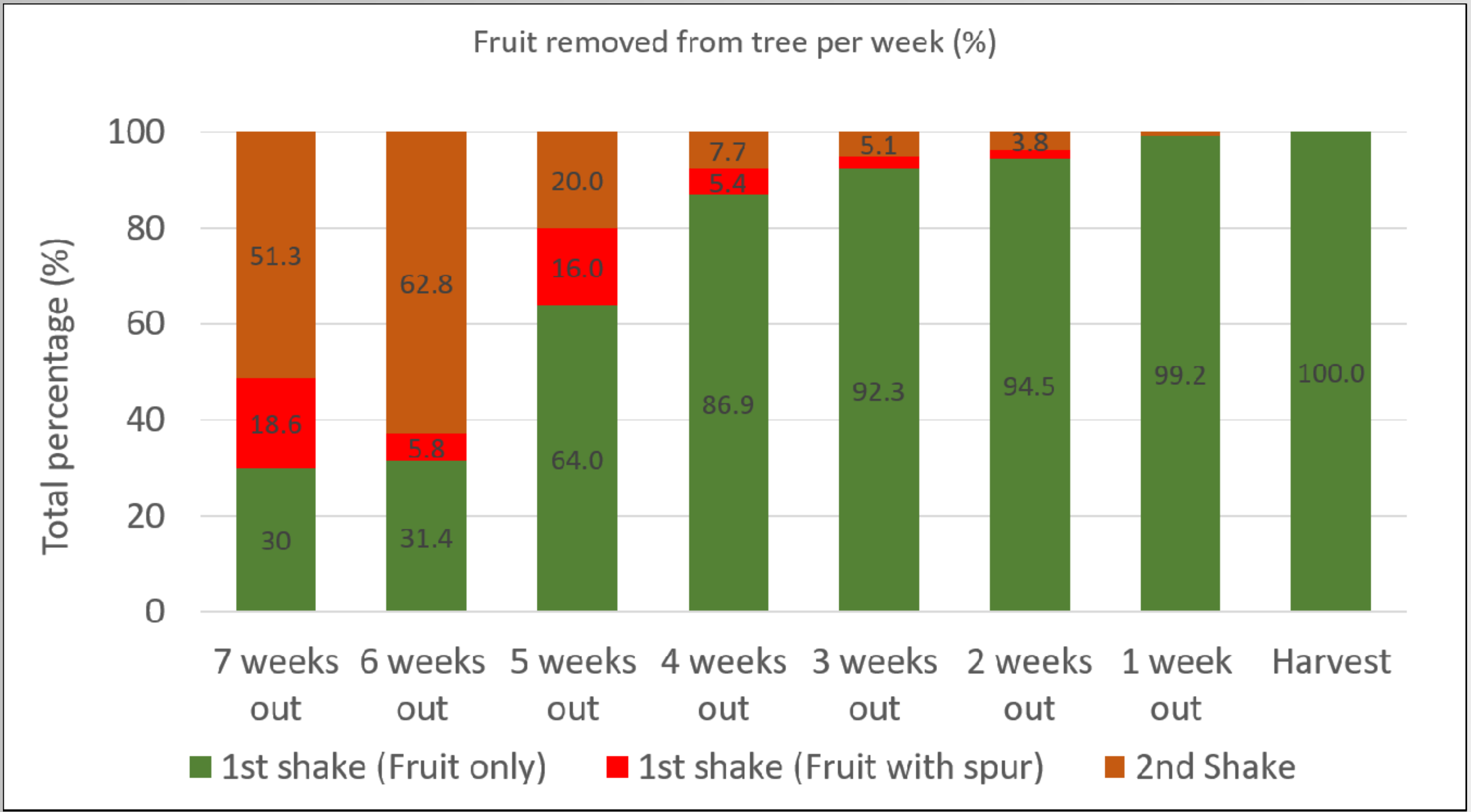
5 weeks out

4 weeks out

Barking

Water restrictions were extended with each week 2-5 days

# Spur damage

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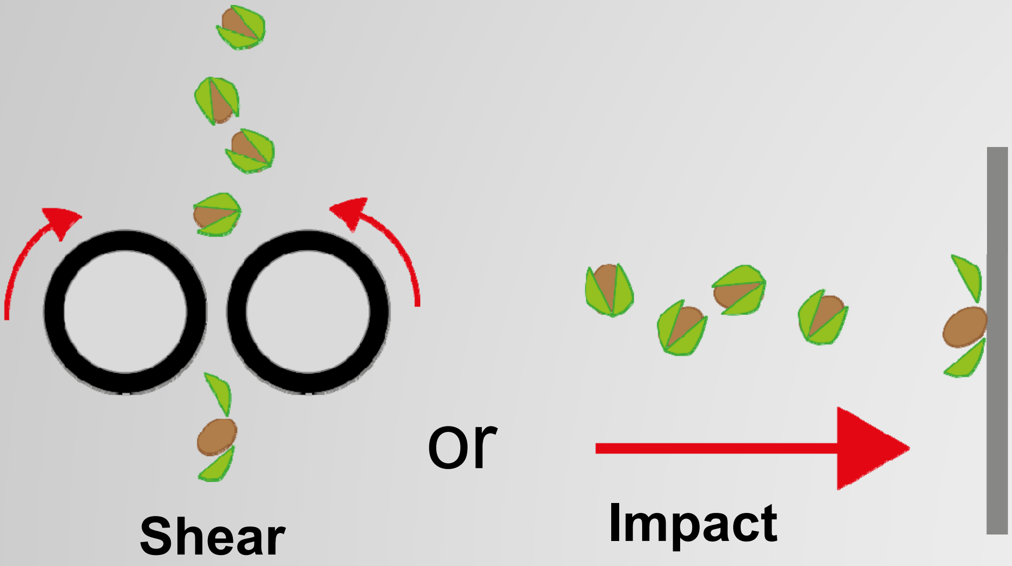
# Shake and Catch

- Work in progress

http://www.theolivecentre.com/Olive-Equipment/Mechanical-Harvesters/COE-Olive-Harvesters.html


## In-field hulling

- Moisture dependant
- Hull separation
- Hull milling

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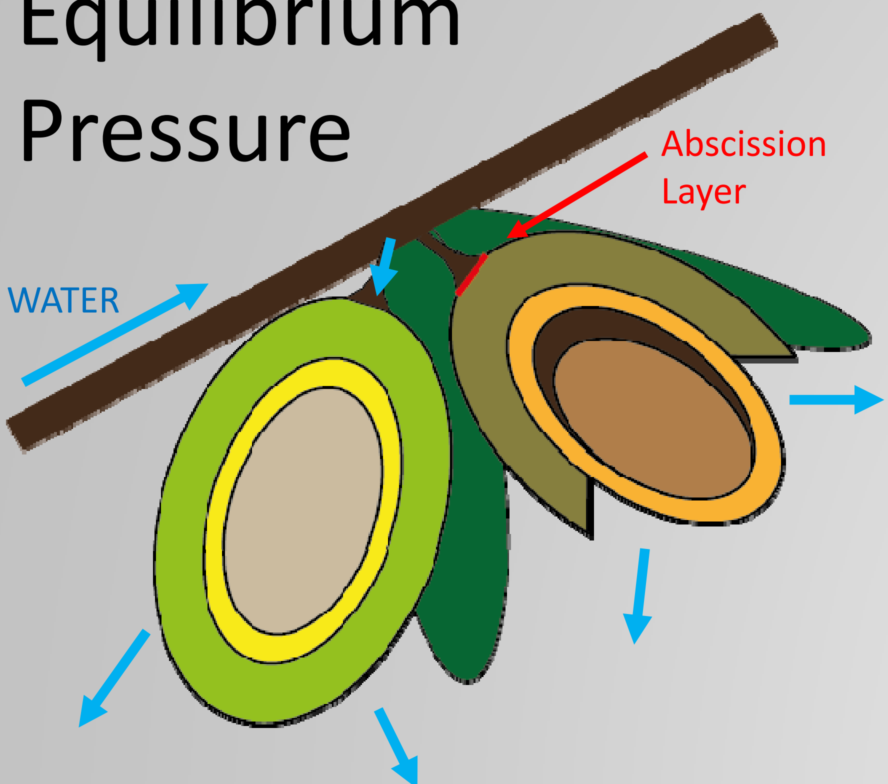
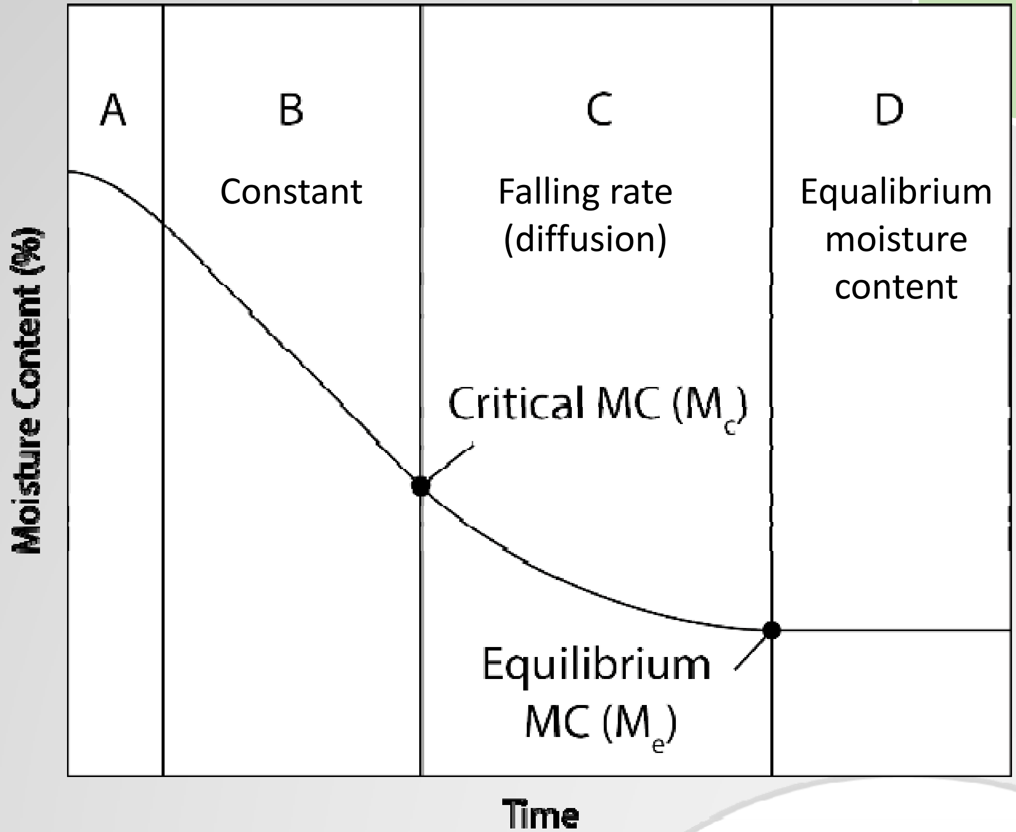
# Mechanical Drying

Equilibrium Pressure




Hull: 13%   Shell: 9%   Kernel: 6% @~25°C (77 °F)

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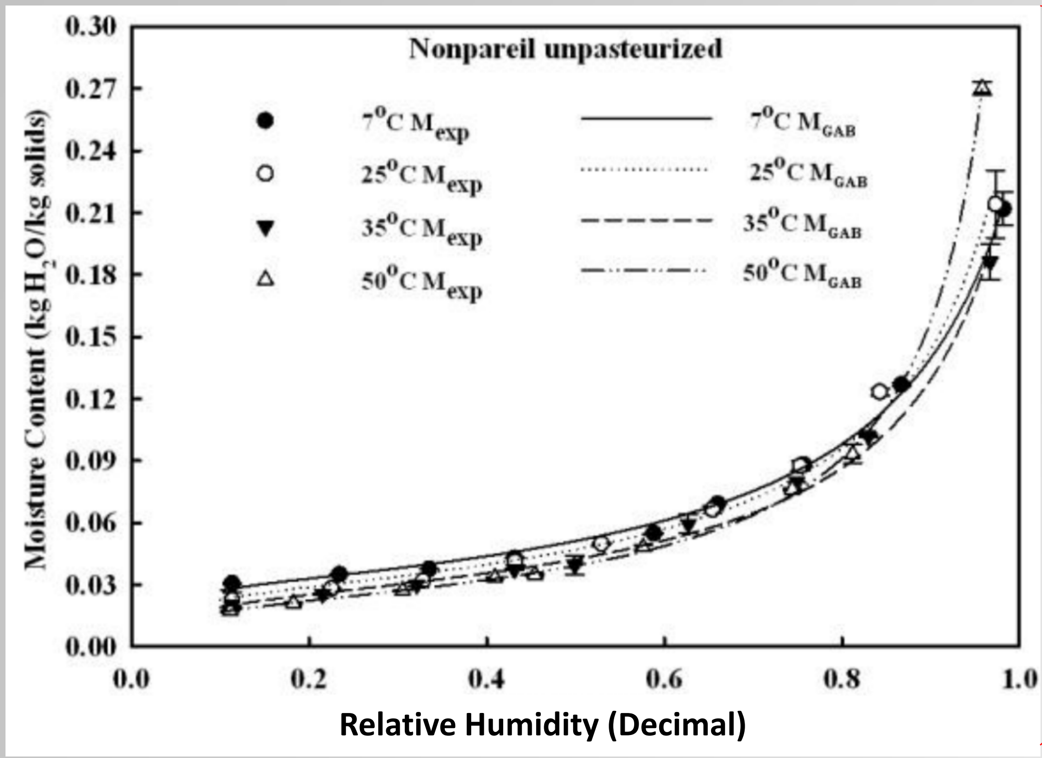
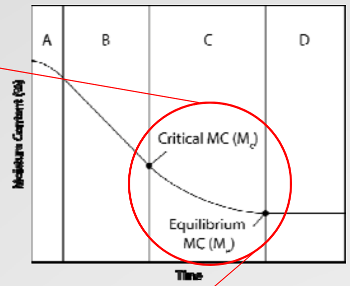
# Mechanical Drying

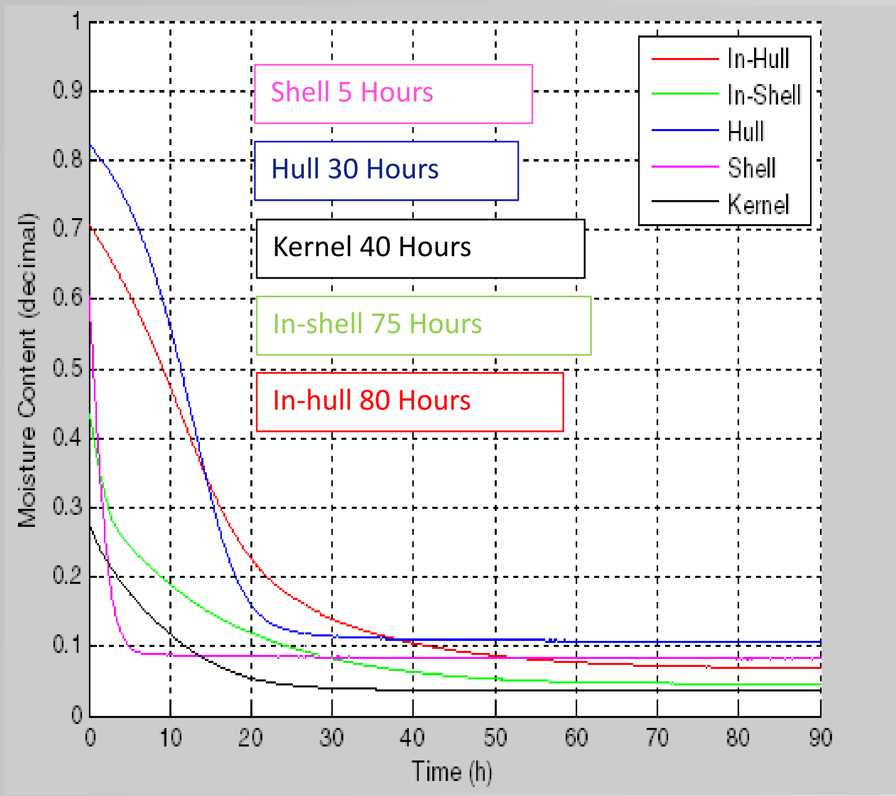



(Taitano, Singh, 2012)



# Drying - Rates

Drying Rates




Carmel 1% hull split @ 50°C

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# Drying - Cavities

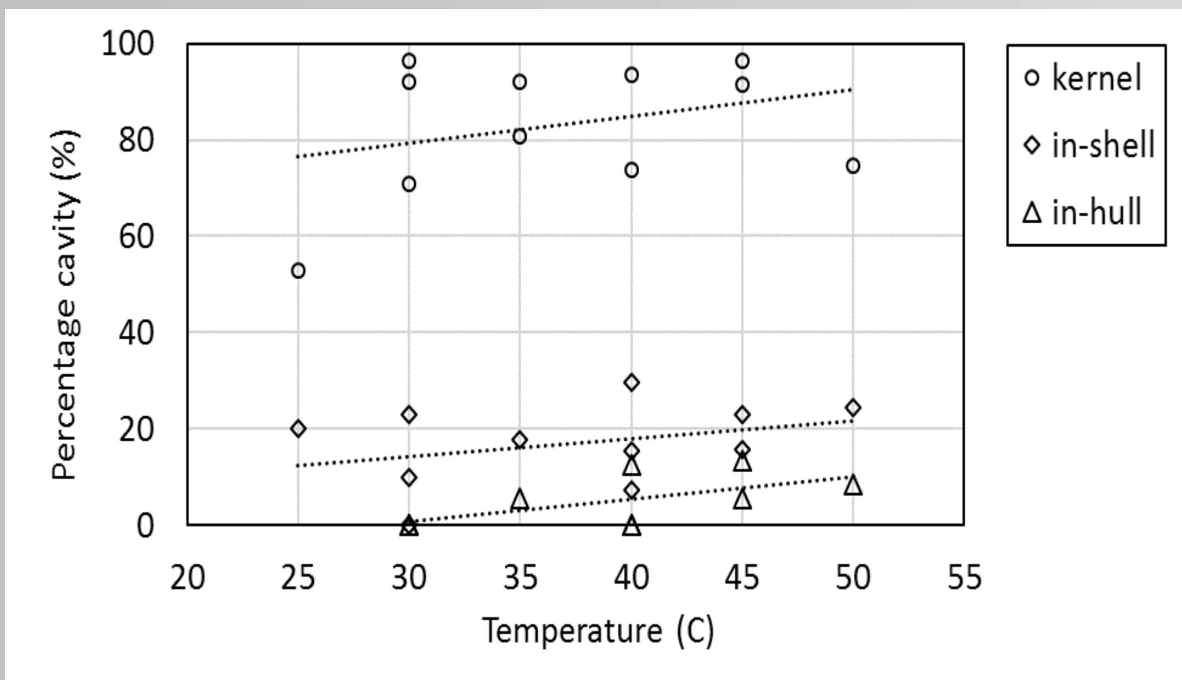
# Drying - rates


**Non-uniform (intermittent) Drying**

**None or short bursts of heat.**

# Drying - Cavities

Occurrence Mechanical (NP)




Occurrence Natural

| Cultivar | n | Cavity % in-hull | Cavity % in-shell |
|---|---|---|---|
| Carmel | 20 | 7 ± 7 | 10 ± 8 |
| Monterey | 3 | 0 ± 0 | 7 ± 11 |
| Nonpareil | 15 | 3 ± 6 | 6 ± 5 |
| Peerless | 5 | 4 ± 5 | 8 ± 6 |
| Price | 12 | 9 ± 8 | 13 ± 11 |

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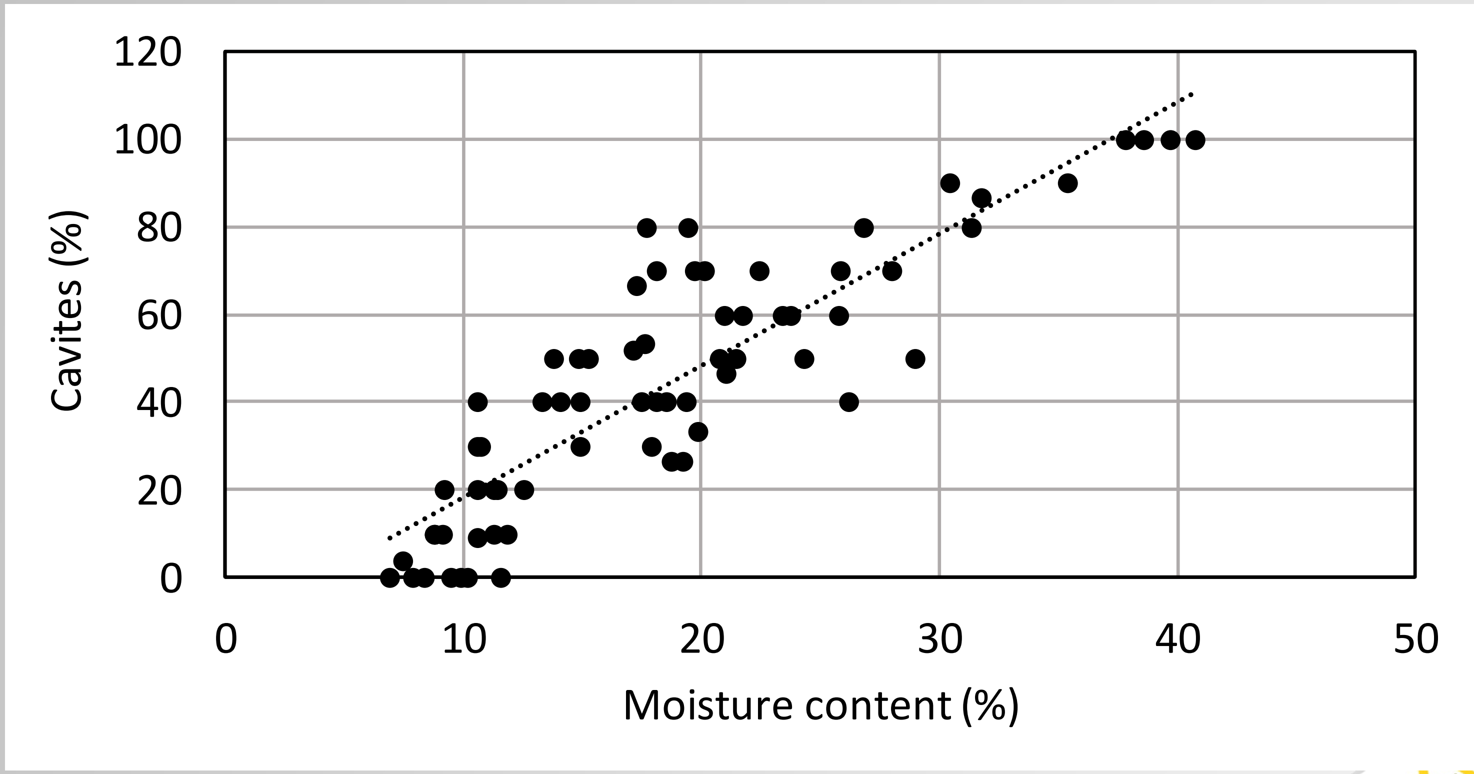
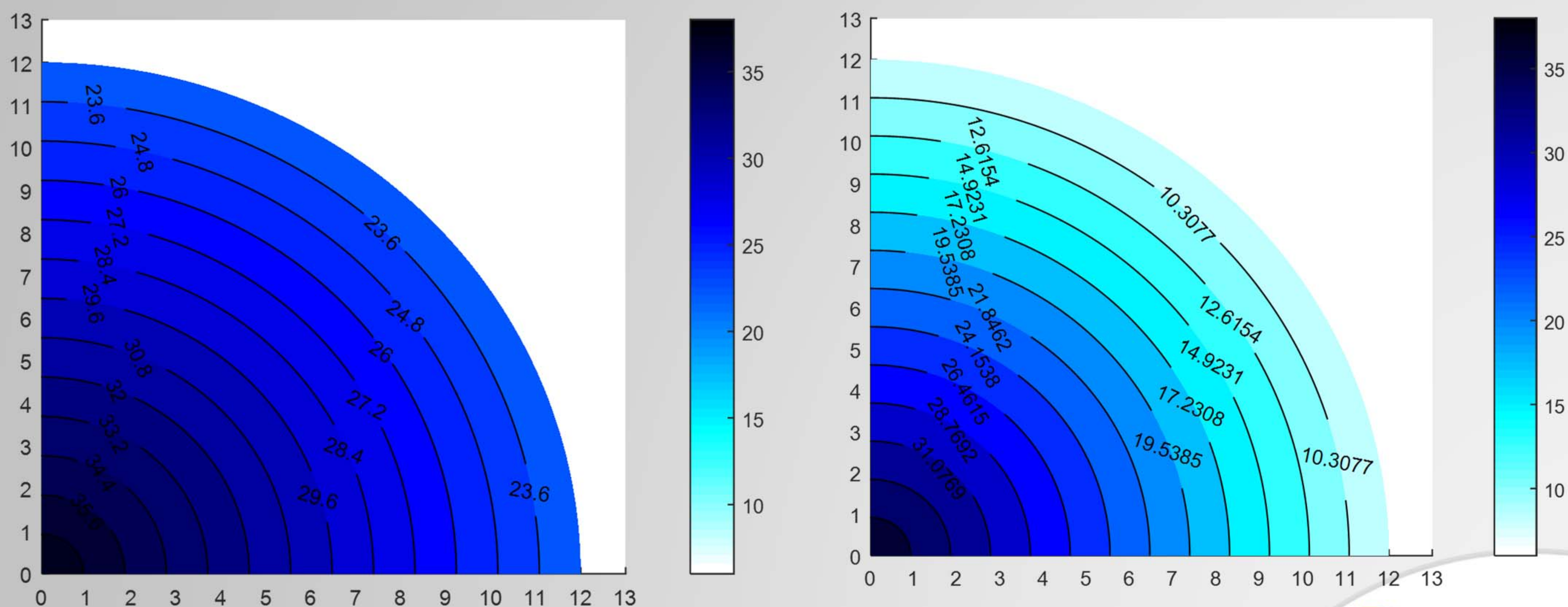
# Drying - Cavities

Cavity probability in almonds dried at constant temperature




Transition Moisture content at ~8% MC

# Drying - Cavities




Moisture gradient and case hardening

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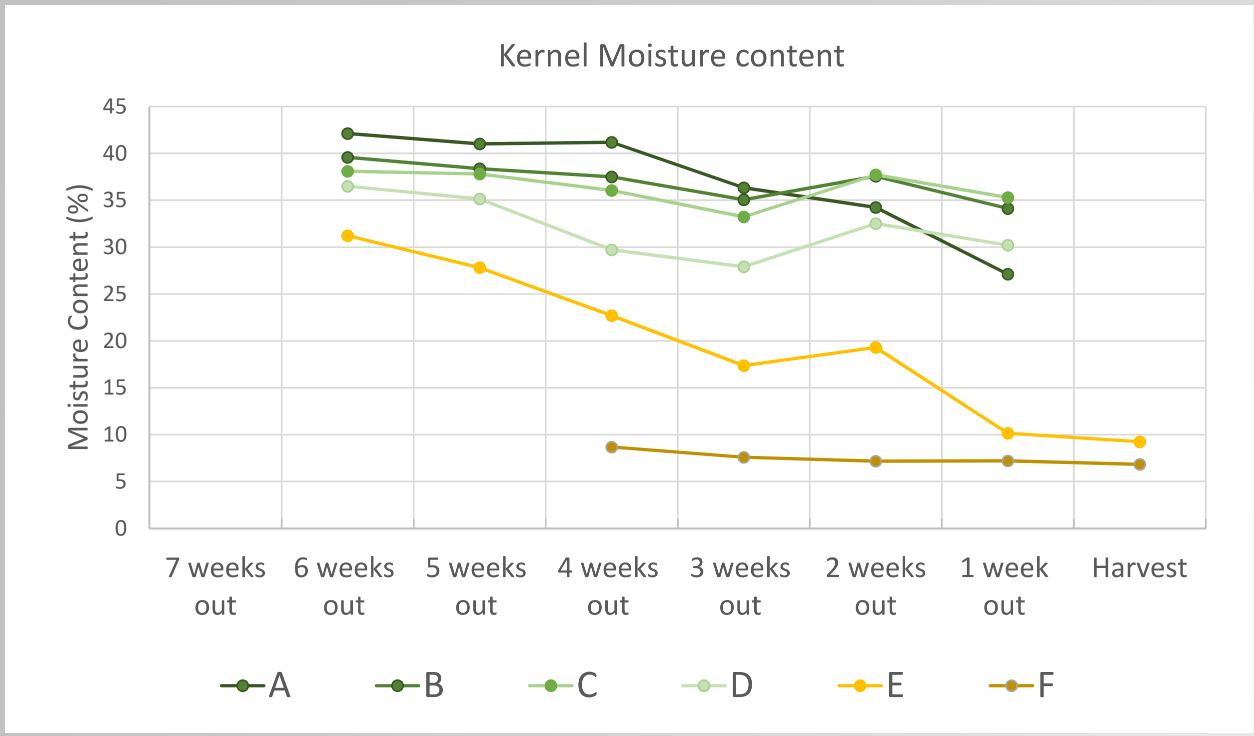
# Drying – How much water




Initial water removal weight using distribution

| Type | 5 weeks | 4 weeks | 3 weeks | 2 weeks | 1 week | Harvest |
|---|---|---|---|---|---|---|
| Water kg / lb | 11.82 / 26.06 | 10.79 / 23.78 | 9.20 / 20.28 | 8.85 / 19.51 | 7.77 / 17.12 | 1.71 / 3.77 |

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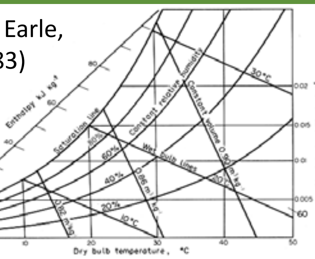
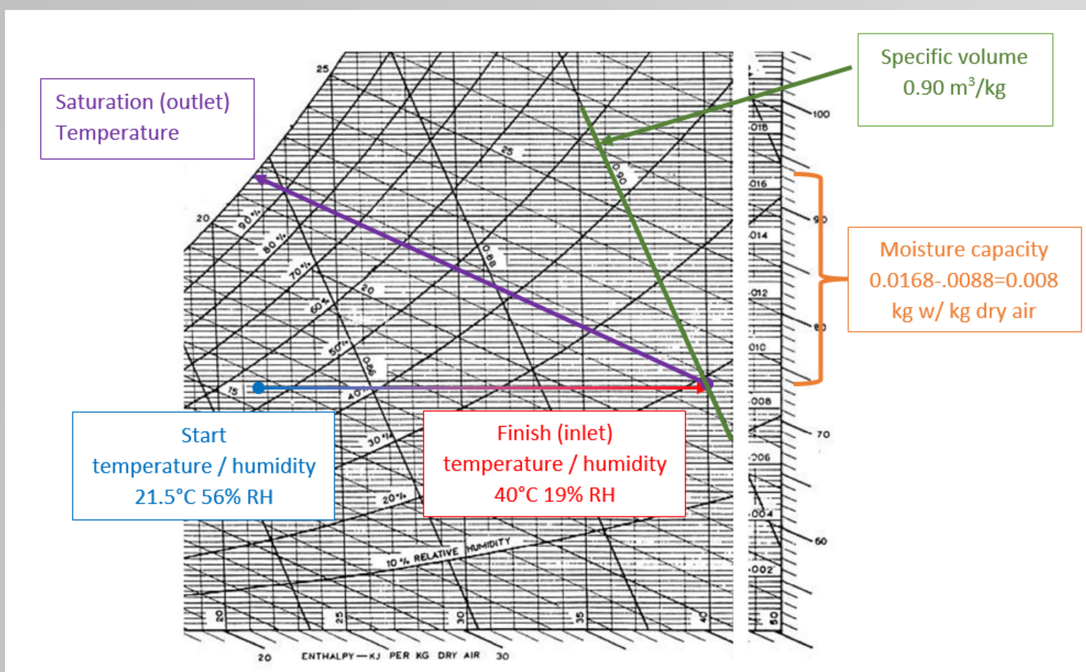
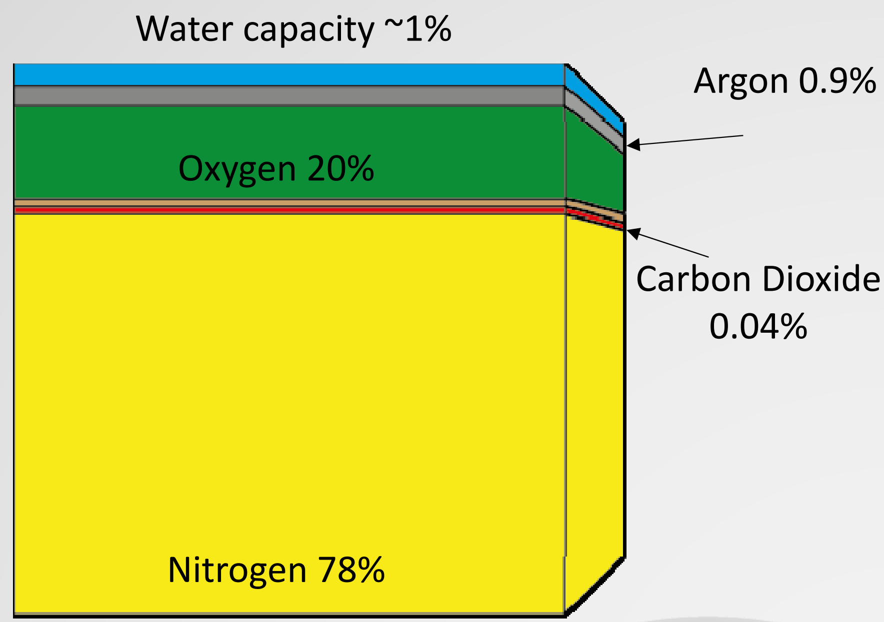
# Psychrometrics


(RL Earle, 1983)

The relationship between temperature, humidity and volume.

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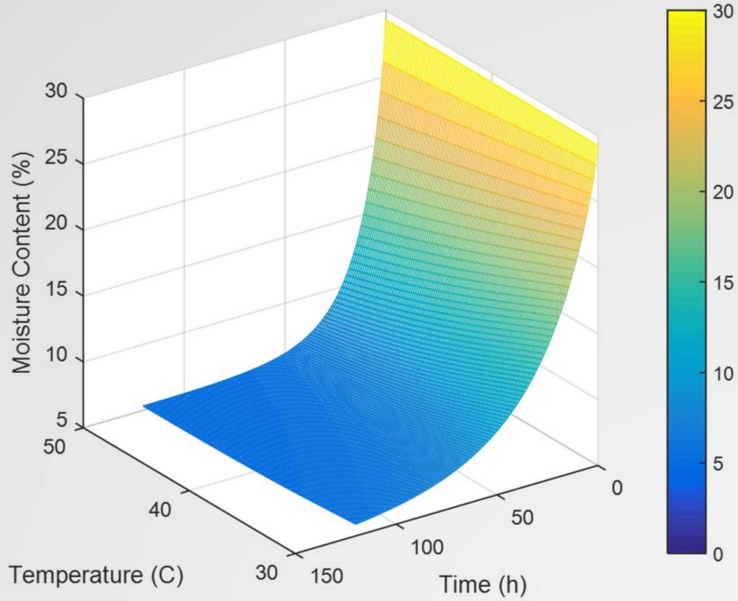
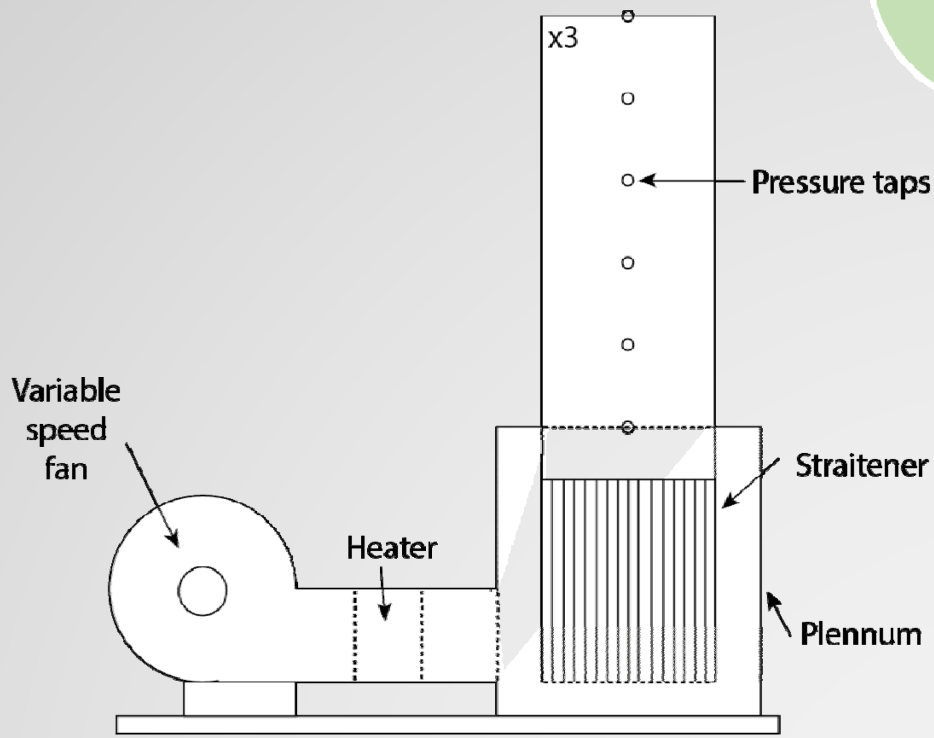
# How much air for how long

**1 meter cube:**
The starting weight for 1 m3 in-shell is **447.159 kg**, at **68%** MC
Overall we need to remove **289.92 kg**, to get to a target **9% MC** (in-shell)
**242.74 kg** in the constant rate, and **47.18 kg** in the falling rate
This takes **14.5904 h** at a constant rate of removal of **2.60446 %/h**
Water wants to be removed at **16.637 kg/h** at 30 C in the constant rate period

**Psychrometrics:**
Ambient T&RH is **30 C** and **40 RH**
Almond Environment is **30 C** and **40 RH**
Moisture Capacity is **0.004 kg water/kg dry air**
This requires **3396.90 $m^3$ air/$m^3$** inshell at **0.94 m/s**
**4443.11 $y^3$ air/$y^3$** in-shell at **3.2 ft/s** (86 F)
This requires **9209.64 $m^3$ air/$m^3$** inshell at **2.56 m/s** (50 C)
**12045.75 $y^3$ air/$y^3$** in-shell at **8.39 ft/s** (122 F)

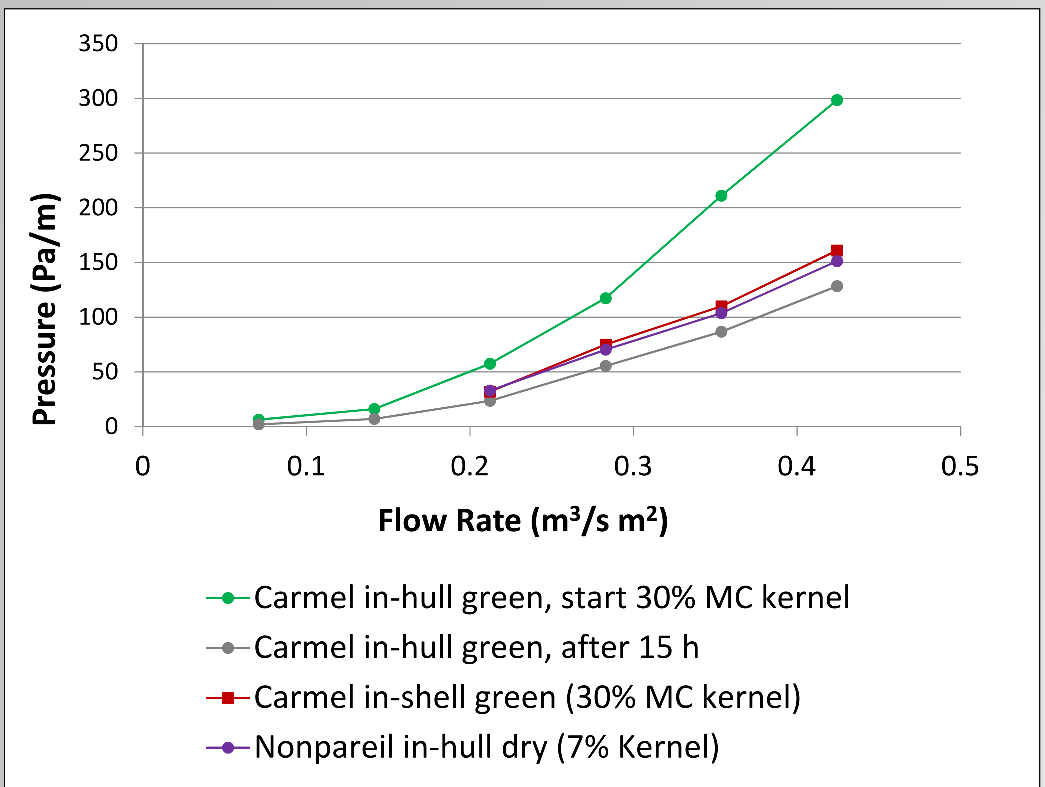


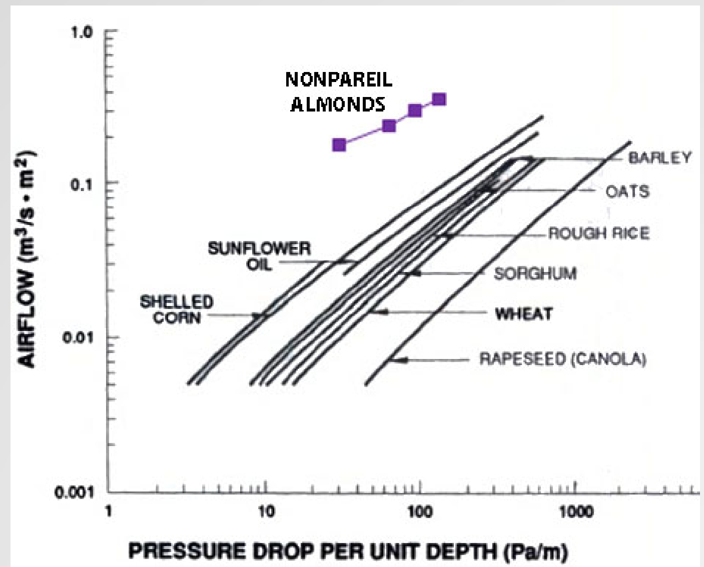
# Drying – Air Resistance



# Drying – Air Resistance

Depth vs Pressure

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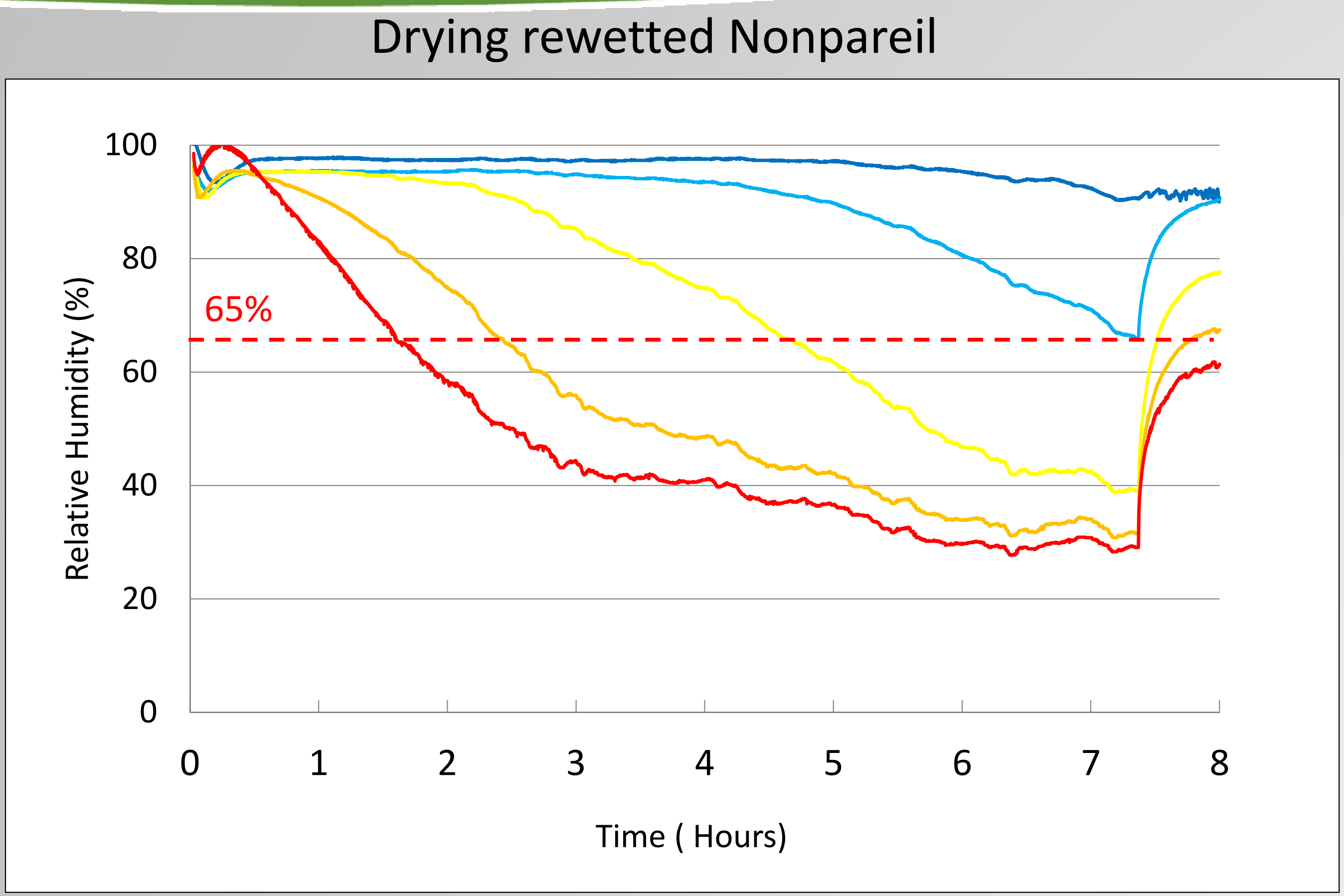
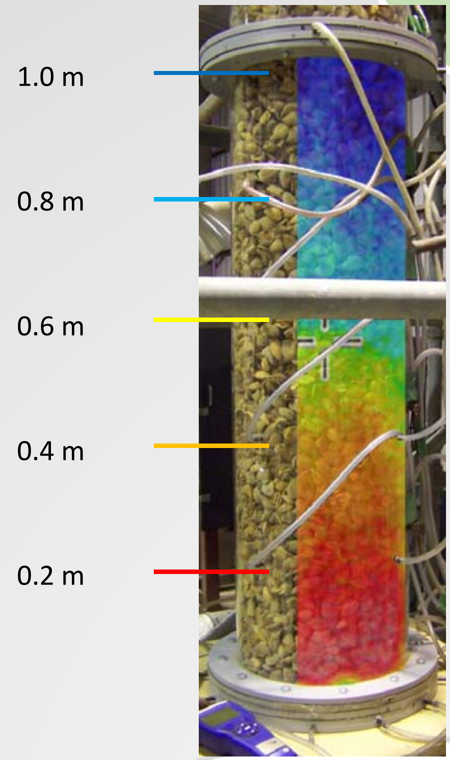
# Drying – wetting front




40°C flowrate of 0.43 m/s

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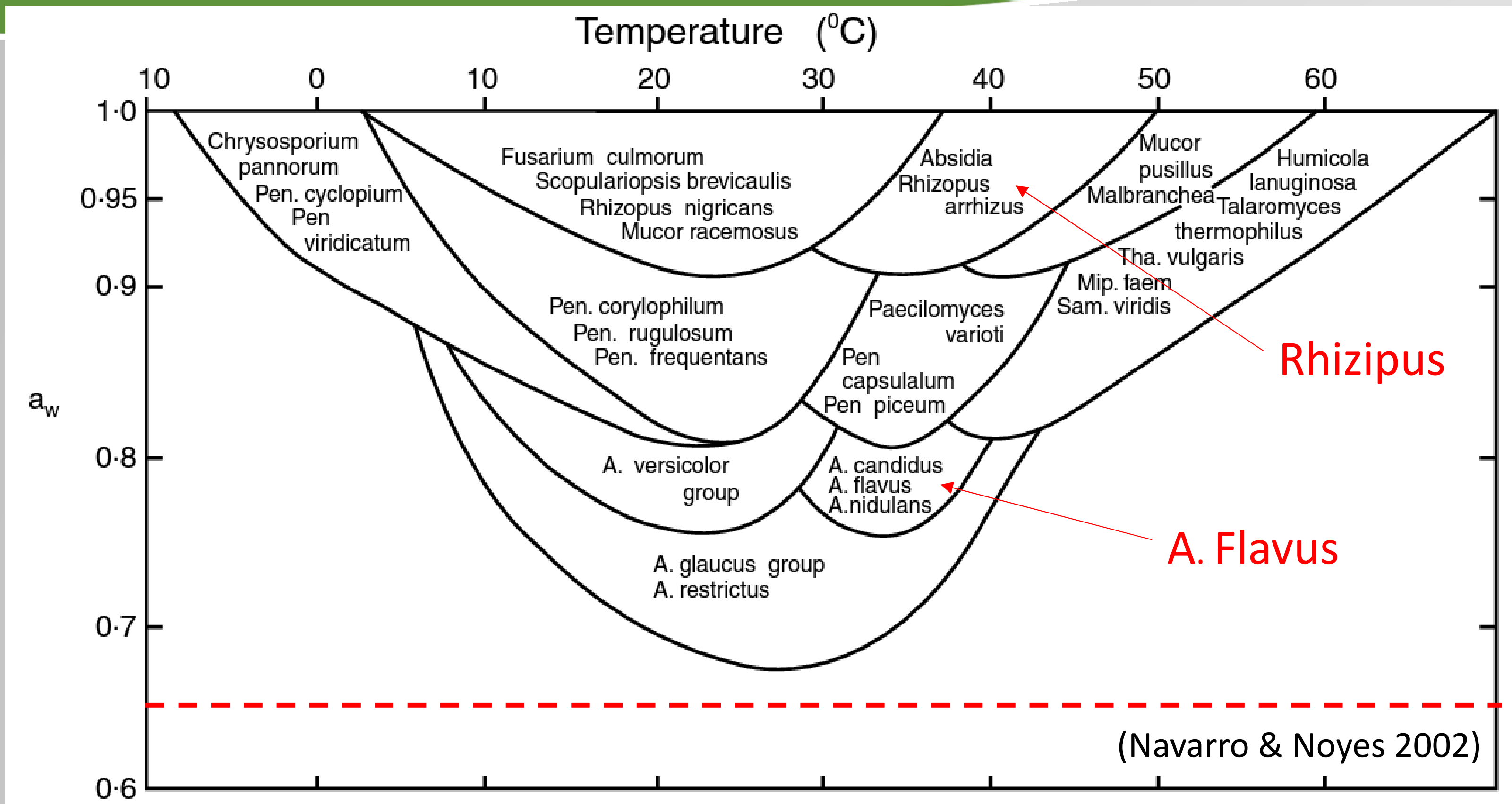
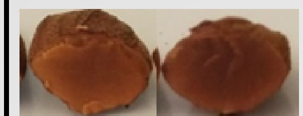
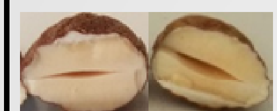
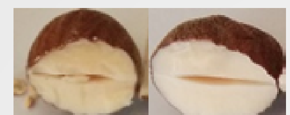
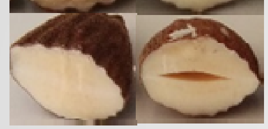
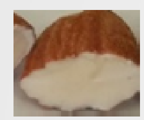
# Drying – Water Activity

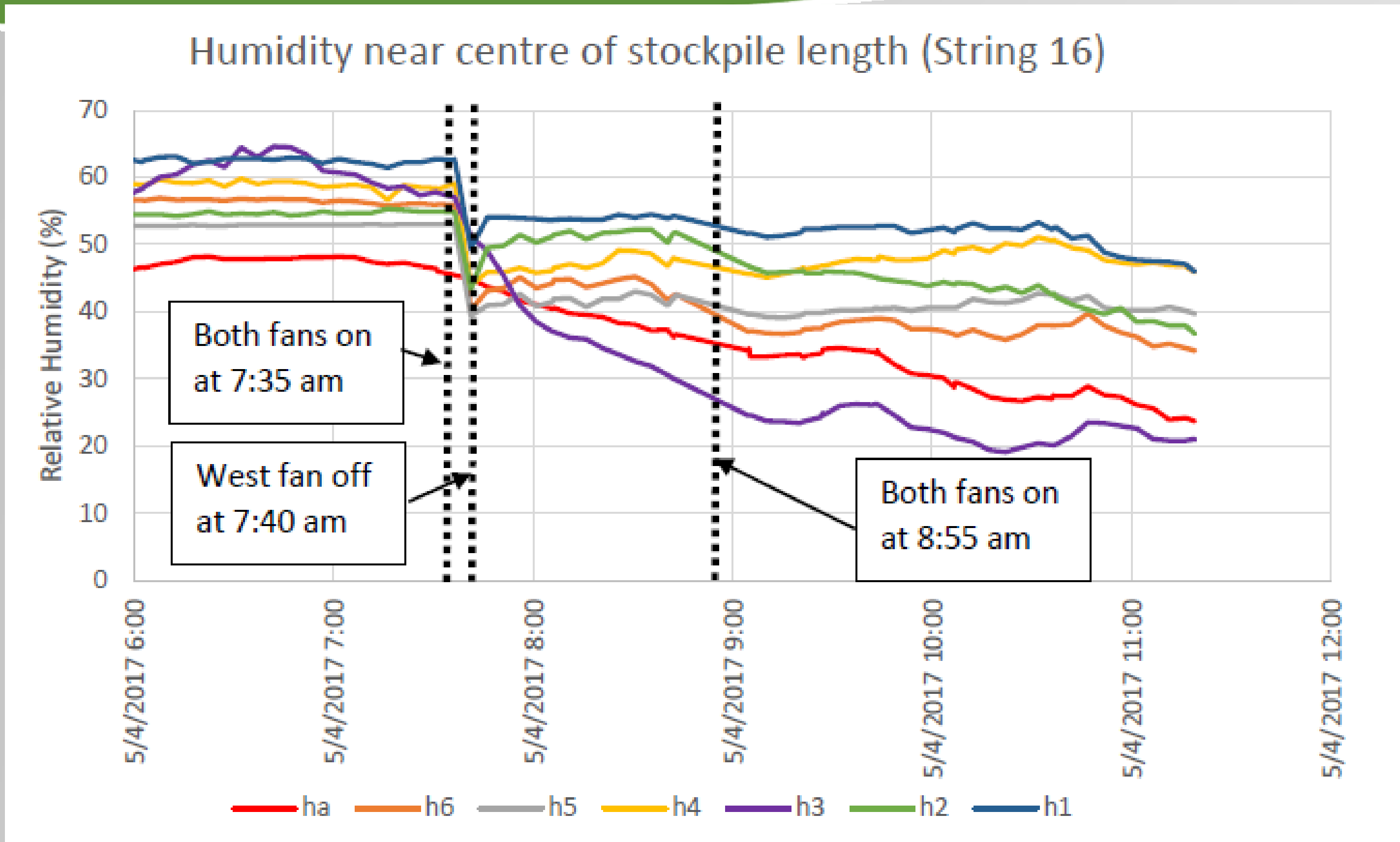


# Drying - CD


| | | E<br>INH INS | D<br>INH INS | C<br>INH INS | B<br>INH INS |
|---|---|---|---|---|---|
| Without Airflow | 50 ° C |  |  |  |  |
| | 45 ° C | |  |  |  |
| | 35 ° C | | |  | |
| With Airflow 1.2 m/s | 50 ° C |  |  |  |  |
| | 45 ° C | |  | |  |
| | 35 ° C | | |  | |

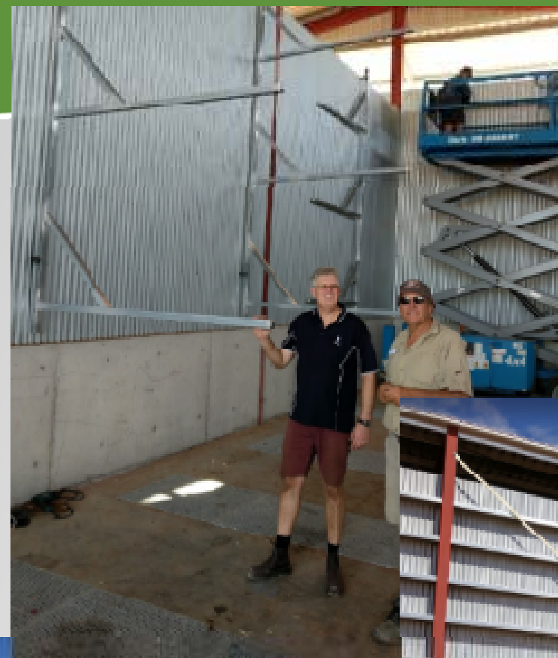
# Aerated Stockpiles


# Aerated Stockpiles



# Shake and Catch

Modify existing equipment (side by side)



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Professor Patrick Brown

The Almond Board of Australia
The Almond Board of California

Walker flat Almonds
Strain Ranch

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