Drying Fresh Harvested Almonds

Project No.: **HARV1.Coates_Gonzalez**

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A. Summary *(In laymen's terms – emphasize key findings and recommendations)*

This project is intended to run in back to back seasons in Australia and California. Unfortunately with the initial funding arriving in mid-February, the project began too late for the first Australian season. This left no time to engineer and build the dryers that we intended to test in the field. Instead we built test silos to see how deep high-moisture fruit could be stockpiled. This gave us a good pivoting point of 10% kernel moisture (M_d). Above 10% M_d, additional resources are required to dry fruit. Below 10% M_d, ambient air is sufficient to maintain a constant drying environment.

In California we started the season measuring the inputs and outputs of the stadium dryers at Almont Orchards. They have been quietly engaged in a second-stage drying process for over 20 years, where in-hull almonds (~10% kernel M_d) are dried overnight in 52ºC air and then hulled the following morning, with a <90% in-shell production rate.

Dr Gonzalez's team at UC Davis built the first batch dryer to begin building a database to associate M_d and temperature with time and air flow requirements. The fruit taken from the orchard (Nickels soil lab) had already dried on the trees below 9% M_d, which limited how much data we could collect. Likewise, the team at UC Davis built the first drying tunnel and tested it at Nickels. The tunnel showed great promise, drying down five tons of 'Monterey' from 12.8% kernel M_d. However, there are changes that need to be made to slow the distribution of air and allow more breathing space for the tunnel.
There was some concern from the growers who are not interested in drying or making stockpiles in their orchard, as this is not common Californian practice, and they would prefer to continue with their existing practices. There should be greater cooperation with

the Australian growers, who traditionally stockpile at their orchards and will be more comfortable trialing drying systems on their existing infrastructure. That being said, we have secured the cooperation of Northstate Hulling and Shelling in Chico where we will conduct the stockpile drying in the 2020 CA season.

B. Objectives *(300 words max.)*

1. Develop aeration parameters for stockpile drying to condition in-hull almonds of different initial moisture levels (9 to 15% kernel moisture content M_d) of three variety types of in-hull nuts (soft shell, semi-hard shell, and hard shell) to reach an equilibrium moisture content of ~5% Kernel M_d: air flow, fan power requirement, stockpile dimension, ventilation pipes, humidity control, aeration time, etc.

   - Construction and validation of stockpile tunnel dryer(s): this is to determine if existing methods of stockpiling fruit can be modified to include drying capacity. One in Australia, built by PFR. One in California, built by UC Davis.

2. Develop drying parameters for heated batch method for high initial moisture levels of in-hull nuts (12 – 18% kernel M_d) of three types of varieties: temperature (35-50ºC), air flow, and drying time.

   - Construction and validation of mobile batch drying station: This is the vehicle that will be used to build a database of time and airflow rates for associated fruit moisture content and temperature. One in Australia, built by PFR. One in California, built by UC Davis.

3. Test effectiveness of dryers on in-hull fruit, maintaining relative humidity (RH) below saturation. Optimise airflow and depth of product: Collect data from objectives 1 and 2 to begin building the database of time and airflow rates for associated fruit moisture content and temperature.

4. Compare stockpile and batch mechanical drying to control. Evaluate the overall performance against traditional methods. Test on multiple cultivars and evaluate for concealed damage, cavities, shell staining and pest damage.

C. Annual Results and Discussion *(This is the core function of this report)*

Year 1 Australian Season

Construction of the batch and tunnel dryers were delayed by a season owing to the lateness of project funding. Instead, test silos were built to measure the temperature and relative humidity on fresh fruit at different depths (Figure 1). Almond fruit has high porosity, allowing ample room for air to pass through. However, the higher the moisture content, the faster moisture comes out of the fruit and if the air is not moving fast enough, the moisture has an evaporative cooling effect on the fruit.

Figure 1. ‘Carmel’ almond fruit stacked into 200-mm, 300-mm and 500-mm drying silos just after shaking. Ambient air can freely enter through the bottom of the silo. Tested at Century Orchards in the 2019 Australian season.

This can drop the average temperature within the fruit by up to 20ºC. This results in a high humidity cold environment that stops drying and promotes mold growth. Fruit around 10% M_d (kernel) showed an even distribution of temperature within the tower that matched the ambient temperature in the shade (~40ºC), while fruit at 15% and higher dropped the core temperature of the fruit into the low 20ºC and retarded the drying process.

This experiment also highlighted the variability of harvest timing, which would be dependent on the available of equipment to shake the trees. It can take weeks to harvest any particular cultivar, thus requiring different drying methodologies at the beginning and end of the harvest.

Year 1 California Season

A batch dryer was built at UC Davis (detailed in materials and methods) and trialed at Nickels soil lab on ‘Aldrich’ fruit with an initial M_d of 8% (kernel) and a final M_d of 4.5% (kernel). The first 12 hours (Figure 2) showed a temperature drop as cool morning air was introduced to the batch dryer and it gradually heated up with the day. But no evaporative cooling was apparent as the fruit continued to heat up, indicating adequate air flow. Heat was added after the twelfth hour, to test the response, showing an increase in temperature and drop in relative humidity (RH). The heater was shut off at night, indicated by the sharp drop in temperature and increase in RH, as cool high humidity air circulated within the batch dryer.

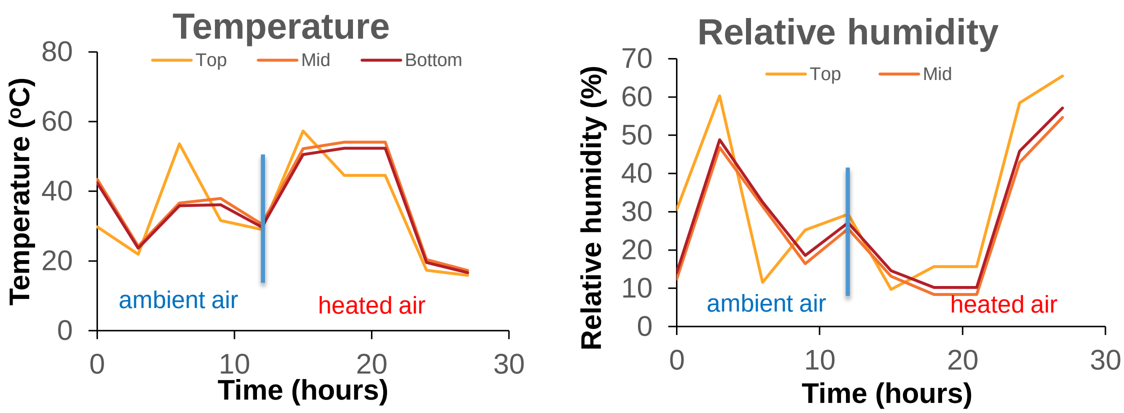

Figure 2. 'Aldrich' almond fruit dried for 12 hours with ambient air and then overnight with heated air, in California in 2019. The lack of increase in relative humidity or reduction in temperature indicates the dryer had sufficient air flow to overcome evaporative cooling.

The dryer design will be modified in Australia to a stadium-style dryer that will allow easier loading and unloading of product as well as fixed sensor locations.

A stockpile tunnel dryer was built at UC Davis (detailed in Materials and Methods section) and trialed at Nickels soil lab on 'Monterey' almonds with an initial M_d of 12.6% (kernel) and a final M_d ranging from of 4.5% (kernel) near the top of the stockpile to 6.5% (kernel) near the bottom of the stockpile. Measurements showed areas of high humidity and low temperature, indicating insufficient air flow (Figure 3).

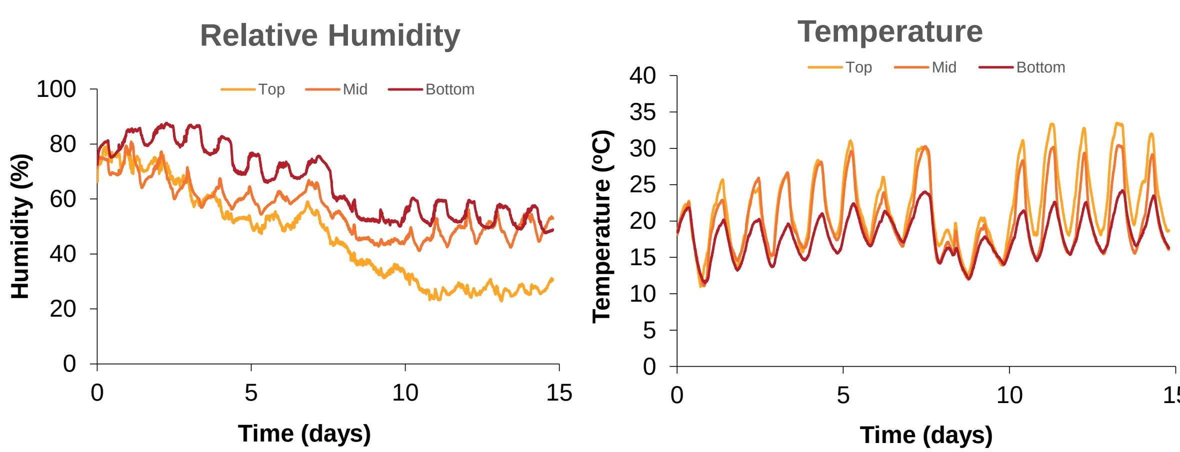

Figure 3. 'Monterey' almond fruit dried for 15 days in California in 2019, showing elevated rates of relative humidity, indicating insufficient air flow as evaporative cooling is taking place.

This will be addressed in the next iteration of the tunnel dryer during the Australian harvest. The airflow into the Californian stockpile was restricted to a 6" tube that fed high velocity air into the tunnel. By reducing the velocity and allowing more ambient air to flow through the stockpile in the Australian dryer, more air should be able to circulate through the stockpile. This should result in drying of almonds in a lesser time, hence reducing energy cost.

In addition to the UC Davis dryers, the team at UC Davis took measurements of the stadium dryers at Almont Orchards. Almont have been secondary drying their fruit for 20 years, bringing fruit into large stadium dryers at 10% M_d (kernel) and drying overnight. Figure 4 shows that while this is a very successful endeavor, they have been wasting energy running their fans at full output.

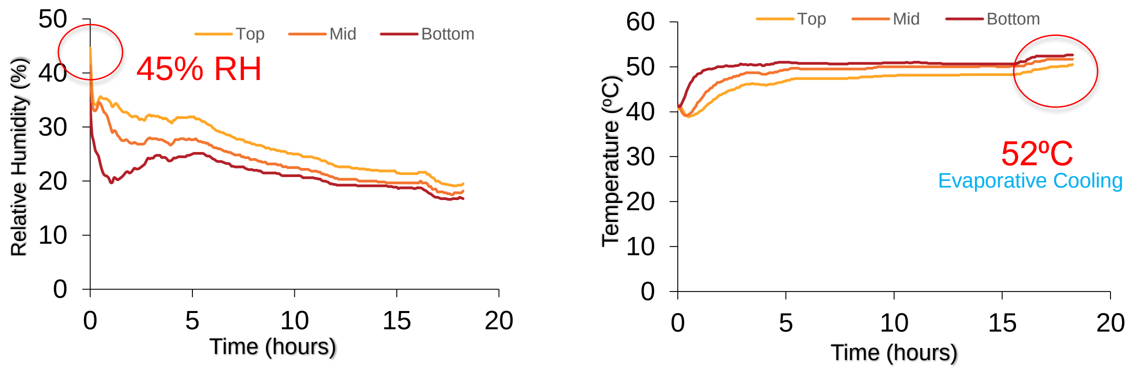

Figure 4. 'Carmel' almond fruit dried for 17 hours in a stadium dryer in California in 2019, showing extremely low relative humidity. Air is blowing too quickly through the stadiums to absorb the moisture coming from the fruit, thus wasting energy.

Almont could potentially reduce the fan speed by half, which would result in reducing their energy expenditure by 75%.

D. Outreach Activities

1. Australian Almond Board (ABA) R&D Conference, Loxton, SA, October 2019
2. California Almond Board (ABC) Conference, Sacramento, CA, December 2019

E. Materials and Methods *(500 word max.)*:

A mobile stand-alone drying unit was built to perform in-field bin batch, and stockpile drying experiments. The drying unit consists of a 12,000-watt dual powered (propane, and gasoline) generator, 2,235-watt (3-hp)/45.7-cm (18-in) diameter propane-heated fan, control unit, air distribution plenum, hoses, sensors, and a weather station to record the environmental and drying conditions during experiments.

While the Australian in-field batch dryer will be built in the 2020 season, an in-field bin batch dryer was developed in California using two bins of 1.2 m (4 ft) x 1.0 m (3.3 ft) x 1.0 m (3.3 ft) dimensions, each containing around 340 kg (750 lb) of 'Aldrich' almonds.

Bins were placed on the top of the air distribution plenum with an opening equal to 0.9-m (2.9-ft) x 0.9-m (2.9-ft), as seen in Figure 5. In-field bin batch two-stage drying was performed by forcing air through the bins using a combination of heated (50°C/122°F), and unheated ambient air at an airflow equal to ~23,263 to 25,286 lpm/m^3 (~23 to 25 cfm/ft^3) of fresh almonds. Twelve T/RH wireless sensors/loggers, six TeleSense sensor-spheres at different heights, and four TeleSense spears were used to record drying conditions per bin.

In-field stockpile drying was accomplished on a 'Monterey' almond stockpile equal to 3.6 m (12 ft) x 2.1 m (7 ft) x 3 m (10 ft) containing about 4,154 kg (9,160 lb) of fresh almonds, and held by a 1.2 m (4 ft) height x 1.8 m (6 ft) metal A-frame. Drying was performed as a combination of heated air 50°C (122°F) and unheated ambient air at an airflow equal to ~3,034 to 4,046 lpm/m^3 (~3 to 4 cfm/ft^3). Drying air was forced through the almond stockpile, using a tube with a diameter equal to 15.24 cm (6 in) connected to the air distribution plenum, as shown in Figure 6. Thirty T/RH wireless sensors/loggers, twelve TeleSense sensor-spheres at different heights and four TeleSense spears were used to record drying conditions.

Figure 5. In-field bin batch dryer at Nickels soil lab, California, 2019 season.

Figure 6. In-field bin batch dryer at Nickels soil lab, California, 2019 season.

TeleSense sensor-spheres and spears were used to provide real-time measurements of ambient conditions and drying conditions, and to allow adjustments of input parameters such air flow and air velocity. However, this was not achieved because of connectivity issues with the company cloud system. This will be addressed by working with the sensing company, and making sure that their connectivity is not affected during future experiments.

Drying air handling within the stockpile was a challenge, as the majority of the air seemed to escape out of the air-frame, and was not uniformly directed through the stockpile. This will be addressed by re-engineering the air distribution method, and potentially modifying the A-frame to better suit our needs.

F. Publications that emerged from this work

1. California Almond Board (ABC) Poster presentation (Appendix A)

Appendix A

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Plant & Food RESEARCH AUSTRALIA

Drying Fresh Harvested Almonds

(Exploring dustless alternatives)

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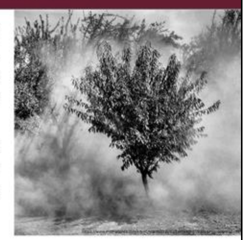
Visible dust is becoming a point of contention between almond growers and the local community as the industry expands into new regions and areas that were traditionally more agricultural and now are becoming more urbanised. Growers are being challenged to address a dust problem that historically had no relevance but now is becoming more of a social issue. While fine dust particles (PM2.5 and PM10) have become more regulated, visible dust has not. This has the industry pursuing a 'good neighbour' policy to prevent further regulation.

One method is 'off ground' harvesting. This requires additional drying to prevent the fruit from spoiling by maintaining a low relative humidity, and warm temperature environment until the fruit reaches an equilibrium moisture content of about 5% (kernel). This project looks to establish the protocols surrounding the airflow delivery requirements to maintain quality within a closed environment (batch) and within an open air, centrally aerated stockpile.



Harvest time Variability

Growers wait until the fruit on the tree is at a stage of 100% hull split, or within the C and F stages in the IPM handbook (Figure 1) (Strand L. 2002). While the fruit may be split, there is significant variation in maturity and the kernel dry basis moisture content (M_d) can vary between 25% (C) and 5% (F), depending on the location in the orchard and the plantings density.

Figure 1. Stages of hull split broken down categorically according to the IPM handbook.

Larger growers can take weeks to harvest a whole orchard, and this mainly depends on the cultivar. Fruit at the beginning of the shaking cycle average around 20% kernel M_d while fruit at the end of the shaking cycle tend to sit at around 10% kernel M_d or less (Figure 2).

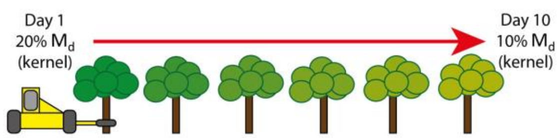
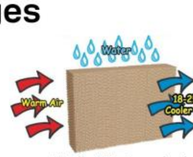


Figure 2. Fruit at the start of shaking can have high moisture content (~20% kernel M_d) and require additional resources to dry, such as additional air and heat, while fruit at the end of the shaking may only require ambient air to dry the fruit to equilibrium moisture content of 5% kernel.

Challenges

Evaporative Cooling (Insufficient Airflow)

This form of cooling takes place when warm dry air passes through a wet or humid zone. The air picks up the moisture causing it to cool. Fruit that takes 3-10 days to dry in a conventional tree row, can take 2-3 weeks to dry.



https://portablecoolers.com/evap/

Concealed Damage (Limited/No Airflow)

This can occur if fruit with a high kernel moisture sits in saturated air (100%RH) for an extended period of time.

Cavities (constant heat at high moisture)

This can occur if fruit with a high kernel moisture dries to fast, usually as a result of too much heat without any pauses. Primarily in fruit over 15% kernel M_d

Skin slippage (high heat at high moisture)

This can occur if fruit with a high kernel M_d (>25%) is heated beyond 60ºC

Batch Drying

A batch drying rig has been developed (Figure 3) to work out maximum and minimum air flow rates at different temperatures for different levels of kernel moisture. Fruit will be introduced at different M_d levels and the air flow rate will be adjusted to maintain a relative humidity around 65%. This will be done for a number of temperatures with the intent of producing a useful chart that growers can utilize to calibrate drying equipment.

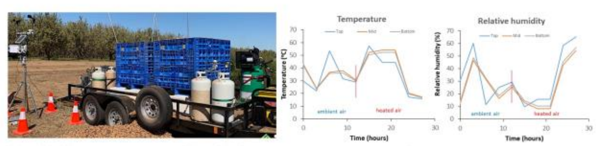


Figure 3. (Left) Batch drying rig developed at UC Davis, (Right) 'Aldrich' results with a starting moisture of 8% kernel M_d. Ambient air is sufficient to dry fruit below 10% kernel moisture.

Stockpile Drying

Vented stockpiles (similar to what was developed at Select Harvest in Australia) are being examined as possible ways to dry fruit in bulk, directly out of the orchard (Figure 4). Different methods will be applied based on the average M_d of the stockpile (Figure 5).

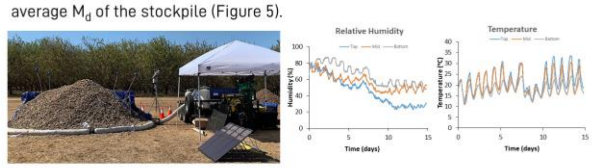


Figure 4. (Left) 11000 lbs of 'Monterey' dried from 12.6% kernel M_d down to 5% kernel M_d. Results showing elevated levels of humidity indicates evaporative cooling is taking place (Right).

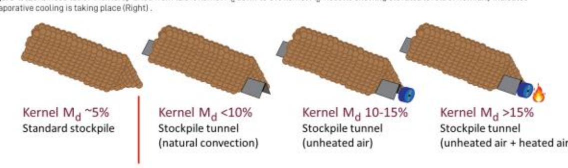


Figure 5. Different methods of aeration can be applied to stockpiles based on the time of harvest and the average kernel M_d.

Summary

- Working to establish the minimum requirements to dry fruit in batches without damaging the fruit.
- Orient the stockpile perpendicular to the wind.
- Thermal mass can keep fruit from over drying.
- Drying tunnel cannot be restricted, air needs to be high volume, low velocity.
- Most growers have not allowed space to stockpile (CA).
  - This can potentially be a roll for the handlers.

Acknowledgments
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References

Strand, LL 2002, Integrated pest management for almonds, 2nd edn, University of California, Statewide Integrated Pest Management Project, Division of Agriculture and Natural Resources, Oakland, Calif.

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