

A model to prevent damage when mechanically drying bulk high moisture almonds



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Overview

Dehydrating high moisture almonds is a new process that requires careful treatment to dry them without developing quality issues such as mould, concealed damage (CD) and cavities. This project investigated dehydration rates and the amount of water that needs to be removed from the fruit. This data was used to develop a model that determines the amount of water, the airflow requirements and time necessary to remove the moisture within the constraints that avoid a quality loss.

Water volume

Dehydration allows fruit to be brought in from the orchard and then dried. All six stages of IPM hull split categories A-F (Fig. 1) are present on the tree at 8 weeks from conventional harvest. Bulk density and category distribution for each category was determined weekly to estimate the amount in kg's of water that needs to be removed (Fig. 2). Optimal conditions for kernel quality were met at a stage of equal hull split (EHS) where categories B – F are equally represented on the tree, this corresponded with 3-4 weeks before harvest (during the 2016 season).

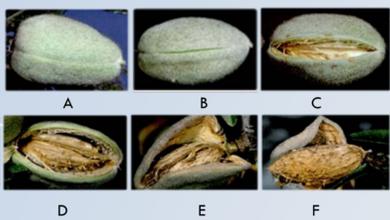


Fig. 1. IPM hull split categories showing progresses stages of dehydration (Strand, 2002).

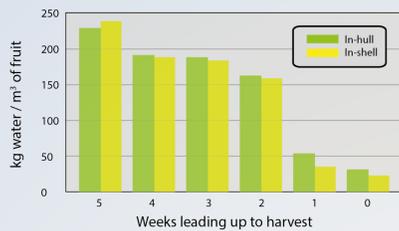


Fig. 2. Amount of water to be removed by week, leading up to harvest.

The rate of moisture loss at each moisture content (MC) for each category at EHS is tracked by the model and then totalled to provide the gross amount of water needed to be removed from the bulk to reach equilibrium moisture content (Fig. 3).

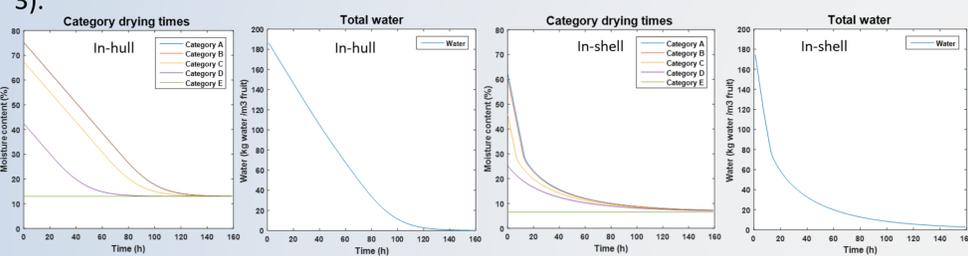


Fig. 3. MC at different hull split categories converted to total water (kg/m³) using fixed 30°C air.

Dehydration rates

Thin layer drying tests were undertaken with Nonpareil in-hull and in-shell fruit at temperatures of 30, 35, 40, 45 and 50°C to determine the constant and falling drying rates. The relationships were modelled (Fig. 4) to develop multivariable piecewise equations that can determine instantaneous drying rate for any temperature and MC.

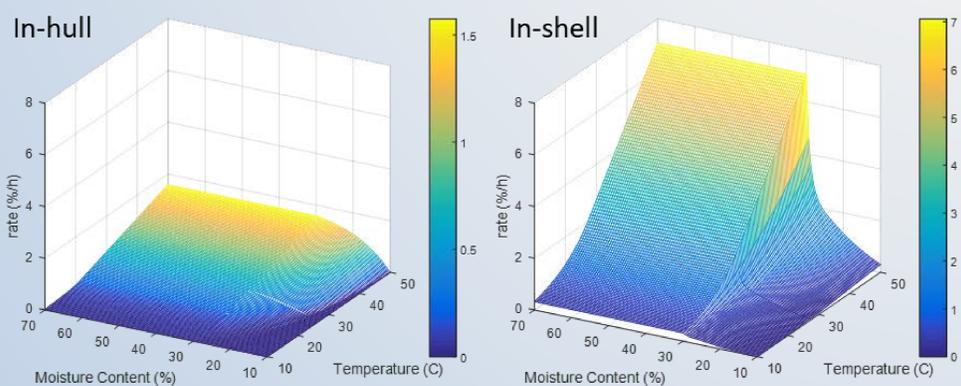


Fig. 4. Drying rates for in-hull and in-shell almonds.

Continuous dehydration of in-shell fruit whilst > 10% kernel MC at temperatures over 40 °C (4%/h drying rate) can produce uneven drying in the kernel that results in case hardening of the outer layers. This stops the outside layers from shrinking though the inside layers continue to reduce in size, thus causing a cavity to form between the cotyledons (Fig. 5 Left).



Fig. 5. Cavities formed within the kernel from drying high moisture kernels at rates greater than 4%/h. (Left), slow dried kernels (Right)

Airflow rates

Individually, a piece of in-hull fruit holds a greater amount of water than in-shell. However, the diffusion rates of in-hull are much smaller. In bulk, 1 m³ of in-hull and 1 m³ of in-shell have similar amounts of water, but in-shell can shed water 5x faster. To maximise drying rates; in-shell fruit requires more air flow than in-hull (Fig. 6).

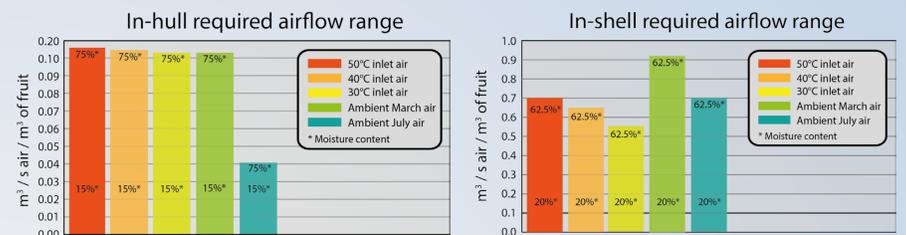


Fig. 6. The range of airflow requirements to displace water in bulk high moisture almonds.

Quality concerns when bulk drying almonds can come from under supplying air. The environment within the bulk is controlled by exchanging the air. Ideally the RH within the bulk should be maintained below 65% which is the equivalent of 0.65 water activity. This prevents moulds and bacteria from growing (Fig. 7). During testing mould become visible after about 12 hours when the fruit is near saturation (RH > 90%). If RH within the bulk is left saturated (100% RH), there is a higher chance of concealed damage which effects the flavour and colour of the almonds (Fig. 8).

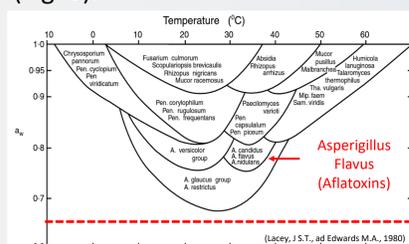


Fig. 7. Water activity levels when various moulds and bacteria grow.

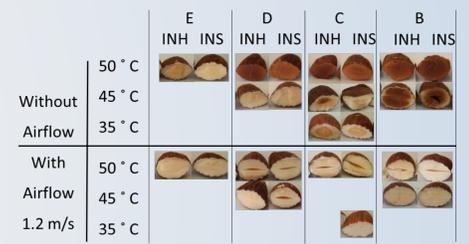


Fig. 8. Occurrence of concealed damage when drying with saturated and unsaturated conditions.

Results

Running the model by heating the air to 30°C as well as using ambient temperatures from the month of March showed that the peak air flow requirements for heated air was 0.16 m³/s air/m³ fruit for in-hull and 0.55 m³/s air/m³ for in-shell (Fig. 9). Values were higher for ambient temperatures being 0.18 m³/s air/m³ for in-hull and 0.80 m³/s air/m³ for in-shell. (Fig. 10). Both scenarios took approximately the same time to complete. Lab scale tests (Fig. 11) showed a good fit when comparing moisture loss between the real data and the predicted data (Fig. 12 & 13).

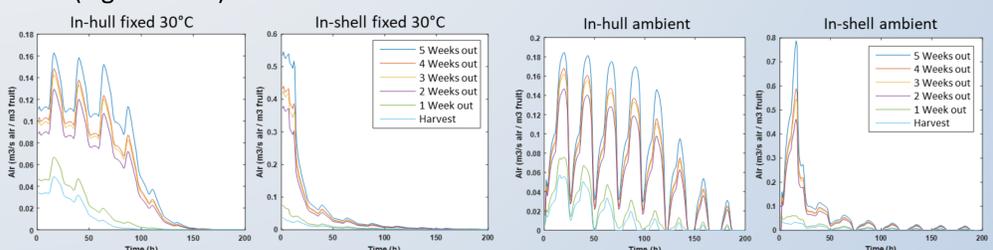


Fig. 9. Required air flow rates for fixed 30°C with ambient RH% from the month of March (2016 season).

Fig. 10. Required air flow rates for ambient temperature with ambient RH% from the month of March (2016 season).



Fig. 11. Lab drying test rig.

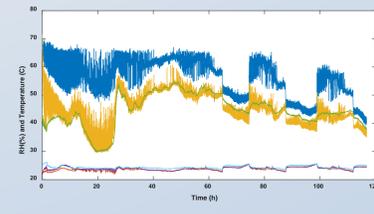


Fig. 12. Experimental temperature and RH data from the test rig.

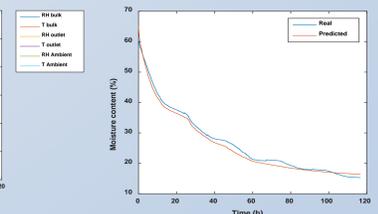


Fig. 13. Comparison of real vs predicted MC for Category B in-shell Nonpareil almonds.

Conclusion

The model performed well in the lab scale testing and shows great promise as a tool for predicting the necessary drying time and the required airflow rates to keep the air surrounding almond fruit in bulk from saturating under high moisture conditions. The next phase of the work will be to compare the accuracy of the model in full scale field tests.

References

- Brimblecombe, P 1996, Air composition and chemistry, Cambridge University Press,
- Lacey, J., Hill, S.T. and Edwards, M.A., 1980. Micro-organisms in stored grains: their enumeration and significance. *Tropical Stored Products Information*, (39), pp.19-33.
- 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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