

SA breathes easier in smarter packaging

Ambient loading relieves logistic pressures, but presents cold sterilisation challenges that can only be resolved with packaging that allows for optimal airflow. By Dr Tarl Berry (Citrus Research International and Stellenbosch University)



The volume of citrus fruit exported from SA under phytosanitary requirements has increased over recent years, resulting in pressure on the limited precooling facilities at local ports. The fact that more citrus is being exported than the precooling capacity available, leaves the industry with a logistical headache.

In response to this challenge, ambient loading has become an essential component of the South African citrus industry's cold chain, as it reduces strain on the limited cold store facilities.

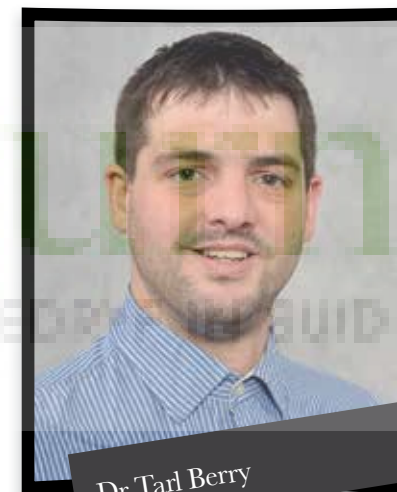
The challenge

Ambient loading simply means that palletised fruit is loaded into refrigerated containers at ambient temperature. The containers are equipped to remove the field heat and cool the fruit over a period of two to three days.

However, current citrus packaging materials are highly resistant to airflow, it can take up to five days before sufficient cold air reaches all the fruit and the set point temperature of $< 2^{\circ}\text{C}$ is achieved. These variations in cooling performance (rate and uniformity) mean that ambient loads do not always meet the requirements of the sterilisation protocol set by full cold sterilisation markets. These loads can, therefore, only be exported under shipment durations long enough to allow for adequate exposure days between the port and the destination market.

The main factors influencing cooling performance of fruit loaded at ambient temperature are the initial pulp temperature and variation in the airflow rates through the pallets. Airflow rates are, in turn, greatly influenced by carton designs and the extent to which they can make the most of a container's air delivery system.

Figure 1: Temperature gradient of ambient loaded (warm) citrus fruit during refrigerated container shipping. This CFD model was used to predict to what extent cooling is delayed when packing citrus fruit with unventilated trays in open-top cartons.



Dr Tarl Berry



Sung-hee Chung

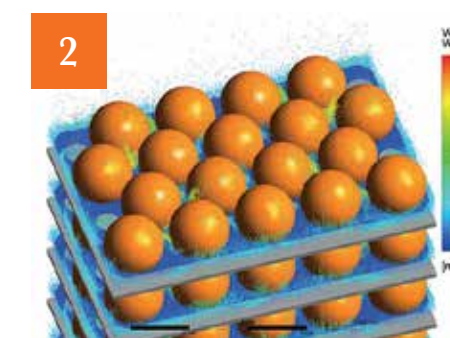
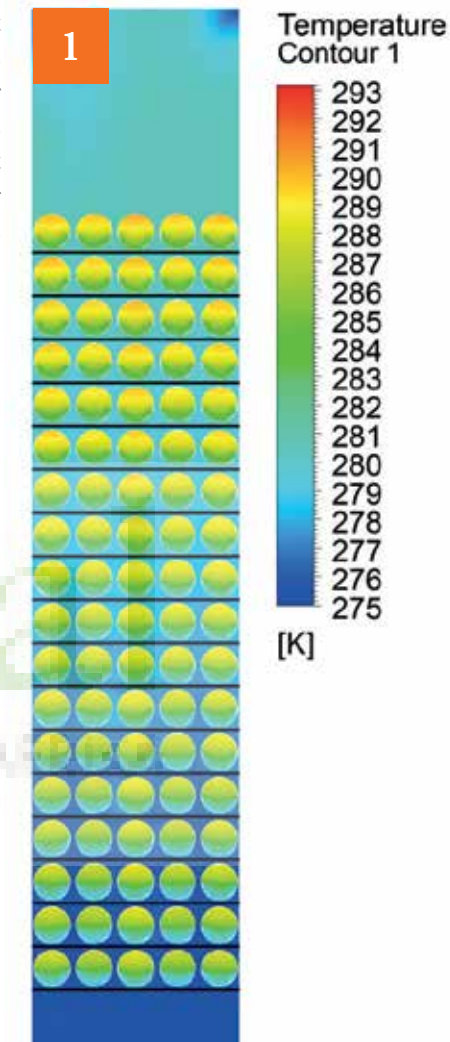


Figure 2: Predicted pathways of airflow between fruit when packed with ventilated trays in open-top cartons

The varied airflow distribution observed in refrigerated containers contributes to an increased incidence of chilling injury (in high flow areas) and pallet hot spots (in low flow areas).

By improving the ventilation capabilities of packaging systems, the use of ambient loading can be extended to further reduce the pressure on SA's limited precooling facilities. Handling times will also be shortened, resulting in faster shipping and the associated benefit of fruit reaching destination markets quicker.

Finding the answers

In an effort to address these issues, Citrus Research International (CRI) initiated research to quantify the performance of current citrus packaging designs, and to identify potential solutions or strategies. The study had four specific objectives:

1. Perform a survey of local packhouses to understand the design problem better
2. Design novel carton vent and pallet base configurations based on total unobstructed area
3. Commercially evaluate current packaging systems during forced-air cooling and refrigerated container shipping
4. Compare the cooling performance of current designs and identify potential solutions for optimisation.

Co-funded by the Postharvest Innovation (PHI) Programme, the study was led by Dr Tarl Berry a researcher for the CRI and Department of Horticultural Science at Stellenbosch University. He was assisted by Professor Paul Cronjé and Jade North-Dewing (an MSc student), both from CRI and Stellenbosch University, and Sung-hee Chung, a post-graduate student at Stellenbosch University.

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Project methodology and findings

The packaging systems survey was performed in 2019 and 2020 using cartons collected from multiple cold stores in Durban, Gqeberha and Cape Town. The evaluation included carton dimensions (footprint and height), vent hole design (size, positions and number) and the palletisation method. The latter included an investigation into the effect of additional packaging material (e.g. securing sheets and trays), as well as how pallet bases restrict airflow.

All the packaging systems were evaluated by emulating precooling as well as container cooling.

The survey results showed that 85% of

Above and right: Clearly the ventholes of the boxes on these pallets do not allow optimum ventilation

SA's citrus exporters use A15C, E15D and E10D cartons. The open-top cartons (E15D and E10D) cooled substantially slower than the A15C cartons.

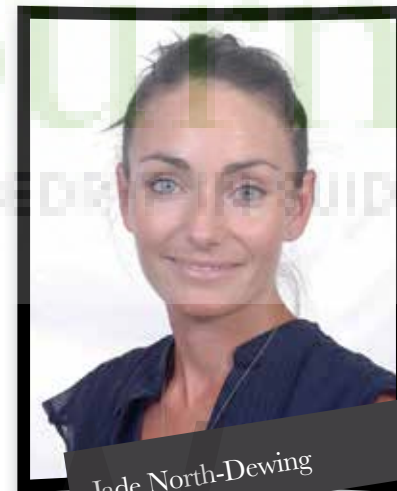
Researchers further found that cross-stacking caused severe restrictions; in fact, where carton layers meet, the resistance to airflow increased more than threefold.

Findings also showed that the packaging system must be considered holistically.

For example, optimising the pallet base to improve ventilation is only beneficial when



Paul Cronjé



Jade North-Dewing

the rest of the pallet is optimised, and non-obstructive securing sheets reduced airflow resistance by 45% and 18% for the E10D and E15D cartons, respectively.

As far as vent hole design is concerned, open-top cartons must have much larger vent hole areas than A15C cartons to achieve similar cooling performances. Future carton designs should furthermore adopt the 100 mm-grid approach, which drastically improves vent hole alignment during stacking. This approach can, in part, address vent hole obstruction during cross-stacking. The 100 mm approach also makes it easier to design pallet bases with more optimal slot positions, which could improve ventilation by ~10%.

The use of trays in cartons greatly increases

A significant finding of this study was that the pallet structure primarily operates as an electrical circuit.

the probability of higher temperatures during shipping. Unvented trays increase pressure loss by 110%; ventilated trays increase pressure loss by 56%. Trays should be avoided at all costs in phytosanitary-sensitive markets. However, if trays must be used, they need to be ventilated.

The way forward

The research study showed that improving ventilation is not a simple matter. For instance, given the extent to which cross-stacking restricts airflow, column stacking should be the preferred method to improve cooling performance. However, column stacking compromises the pallet's overall stability. Stability issues must therefore be addressed first.

A finding that the industry has already actioned is that using correctly designed securing sheets would be one of the most practical ways to reduce airflow resistance in open-top citrus packaging. Furthermore, EU markets are now required to use ventilated trays and securing sheets that are designed with non-obstructive vent holes.

Despite its many useful and significant findings, the study showed that a singular recommendation regarding vent holes is not possible. While cooling is primarily determined by the ventilation holes in a carton, a great number of other variables interact with vent hole design. To resolve the design problem, a more dynamic approach is needed.

A significant finding of this study was that the pallet structure primarily operates as an electrical circuit (Kirchhoff's first law of circuitry), with the fan, carton interiors and vent holes functioning as "batteries", "wires" and "resistors" respectively. Flow

rate is thus current, pressure is voltage and constriction/obstruction is resistance. A similar approach is applied by the mining industry, where complex ventilation systems are likewise calculated.

This modelling approach can be used to describe the whole pallet structure as a 3D flow circuit and, with the correct parameters, characterisation of the system is possible almost instantaneously. Furthermore, the model could be used to generate performance indices for every possible packaging scenario, resulting in a practical guide the industry can use for ventilation design. This concept is currently the focus of a Meng research project and is showing promising outputs. ▶

The project's economic impact

Chilling injury related damage equates to millions of rand in losses per year. The findings of this study are already being introduced at multiple levels, into industries packaging, resulting in more effective phytosanitary applications and the need for less destructive cold treatment applications.

Project information

Project title: Integration of pallet bases and carton designs to improve ventilation of containerised citrus exports
Principal investigator: Dr Tarl Berry
Duration: 01/03/2019 — 30/07/2021
PHI Programme and industry contributions: R284 385 and R284 385
Lead institution: Stellenbosch University
Beneficiary: The South African citrus industry
Human resource development: 2 PhD students, 1 MSc student and 1 MEng student
Focus area: Carton design, cooling, pallet design, postharvest quality