Integrated packaging solutions

Unpack the box

Boxes and cartons are more than containers in which fruit is transported. They are also the keepers of fruit quality. Their design is finally getting the attention it deserves.

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About 90 million cartons are used annually in the export of citrus fruit and about 46 million in the pome sector.

THE BOXES IN WHICH FRUIT TRAVELS from the pack house to the shop have long been a neglected link in the export chain. Annual global fruit losses are staggering – as much as 40% – and poor packaging design has to shoulder part of the blame.

Without packaging fruit cannot be moved efficiently and in large quantities. The need for sound packaging to protect fruit against mechanical damage is well understood. The same cannot be said for the impact of packaging on other fruit quality attributes, as well as cooling efficiency and energy costs.

Packaging design for the fruit export industry is particularly challenging. Fruit lives and breathes and releases heat and moisture. If it is closed up in a container, microorganisms may grow and cause decay.

1 Prof. Linus Opara.

2 These computational fluid dynamics (CFD) visualisation of core fruit temperature show that fruit cools faster and more uniformly inside Supervent cartons than in standard A15C cartons.

Fruit needs to take in air and cool down to maintain its quality.

Forced-air cooling is generally used to cool fruit to required storage temperatures, while ventilated packaging helps to remove excess heat from inside and around the fruit to reduce respiration rates. It also facilitates rapid and uniform cooling.

A QUESTION OF DESIGN

Producers and exporters can choose from a variety of commercially available packaging options. But how does one know which is the best? There are many factors to consider: the size and number of the vent holes; how well the fruit will be protected and able to breathe, stacked in the middle of a number of pallets inside a shipping container; the impact of packaging on the pack house or cold store's energy bill; the ability of the box to withstand impact, vibration and compression; and the export market's packaging requirements.

These questions hint at the complexity of the packaging issue, and all the problems experienced in the cold supply chain related to inadequate packaging, confirm it. Until recently, however, the industry relied on past experience, anecdotal evidence and the need to trump the competition on aesthetics to guide its packaging design decisions. But that is about to change, thanks to the out-of-the-box approach of a team of researchers that is causing a 'revolution' in the packaging arena.

THE PROJECT

"Existing packaging options are not terrible, but if we accept the status quo, we miss out on opportunities to innovate, reduce cost and add value to our growers in an increasingly competitive global market," says Prof. Linus Opara, from the Post-harvest Research Laboratory at Stellenbosch University. "Innovation will help to ensure that the industry remains profitable, sustainable and internationally competitive."

Prof. Opara led the groundbreaking study that used engineering software to assess the performance of existing ventilated fruit packaging in terms of airflow, environmental control like temperature and relative humidity, fruit quality maintenance, the cost-effectiveness of materials and the refrigeration energy required for cooling. The latter is an important consideration. If the time needed to cool fruit down can be reduced, energy and cost will be saved. At the same time, the fruit's shelf life, health and even ripening process will be enhanced. All this can be achieved by optimising packaging ventilation.

"Our aim was to develop a validated mathematical model, applicable to all kinds of fruit, to predict the cooling performance of ventilated packaging," explains Prof. Opara. The resultant model will be used to design packaging that combines the best possible ventilation with structural strength. "We wanted a model that could visualise the airflow and heat transfer patterns inside and around fruit packaging," adds Prof. Opara. "This would enable us to develop practical guidelines for efficient and cost-effective packaging design. The ultimate intent is to design a new generation of innovative packaging that is light, strong, cost-effective, recyclable and intelligent."

The project team, based in Stellenbosch, consisted of Prof. Opara, Dr Mulugeta Delele and Dr Pankaj Pathare; Prof. Chris Meyer and Dr Corné Coetzee from the Faculty of Engineering; Dr Paul Cronjé from Citrus Research International (CRI)/Stellenbosch University; two post-doctorate and four MSc students.

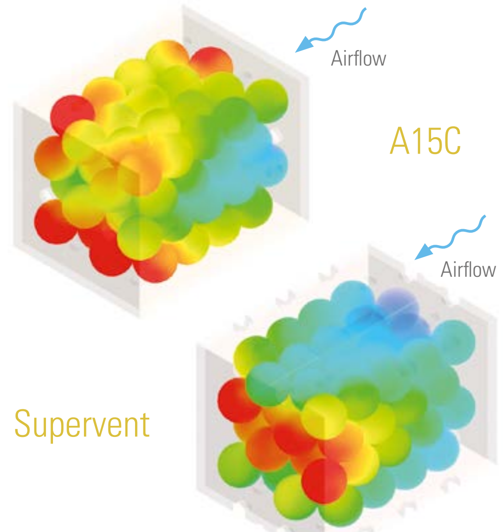
A NEW APPLICATION FOR CFD

Computational fluid dynamics (CFD) is a specialised area in computer and mathematical modelling

WHY PACKAGING NEEDS TO UP ITS GAME

- To limit wastage by reducing, reusing, recovering and recycling packaging.
- To limit the volume of packaging being used, and thereby reduce the industry's carbon footprint.
- To reduce cooling rates and, as a result, energy costs.
- To reduce post-harvest food losses and waste.
- To make the fruit industry more profitable and sustainable.

2 FRUIT CORE TEMPERATURE (SINGLE BOX)



PROJECT TITLE
Packaging of the Future: integrated model-based design and performance evaluation of packaging for the South African fresh fruit export industry

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DURATION
Two years

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LEAD INSTITUTION
Stellenbosch University (Faculty of AgriSciences)

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Integrated packaging solutions

HUMAN CAPITAL DEVELOPMENT
Two post-doctorate and four MSc students

PRESENTATIONS AND PAPERS
Five

PUBLICATIONS
Ten

> "The ultimate intent is to design a new generation of innovative packaging that is light, strong, cost-effective, recyclable and intelligent."
> Prof. Linus Opara

used in industries such as aeronautics and nuclear fire and hazard management. Existing software was not designed with packaging analysis in mind, but the research team used ANSYS FLUENT software to simulate and predict airflow and heat transfer inside crates, fruit boxes, pallets, pack houses, cold stores and containers.

Funding from the PHI Programme, HORTGRO Science and SARChI Post-harvest Technology enabled the project team to purchase access to the CFD software and set up the experimental research infrastructure.

Prof. Opara thinks that this is probably the first time that CFD modelling is used in South Africa to better understand the fruit cold chain, specifically fruit packaging design and improvement. He explains that, when new packaging is designed, the usual process of manufacturing and repeated testing to meet the requirements of different fruit kinds is expensive and time-consuming. The novel approach of CFD modelling saves time and money. It simulates airflow patterns and heat and moisture transfer in and around ventilated packaging, which allows the team to study and predict the effect on fruit cooling rates. Package designs can be digitally assessed on the computer for as many times as necessary before involving manufacturing companies and embarking on three-dimensional testing.

"The strength of the project lies in the ability to test different scenarios beforehand by combining engineering and mathematical modelling with experimental studies," says Prof. Opara. "Without making a single prototype, we created hundreds of packaging vent design variations on the computer."

THE PROJECT FINDINGS

The research team focused their efforts on two main areas. The first was to assess the design of packaging vents to determine the ideal specifications for vent size, shape, number and positioning on the packaging. The second was the effects of storage conditions on the mechanical behaviour of ventilated corrugated packaging.

The team tested different packaging configurations, individual and stacked, during forced-air cooling. Some of the trials were conducted at the Stellenbosch University Post-harvest Research Laboratory and cold store facilities. They collaborated with industry role-players such as pack house operators, packaging companies and cold chain specialists. Outer and inner packaging were also tested for deciduous and citrus fruit. These included the specialised inner packaging for table grapes, such as SO_2 absorber sheets, carry bags and perforated poly-liners. In the long term, all the fruit sectors will be included in the trials.

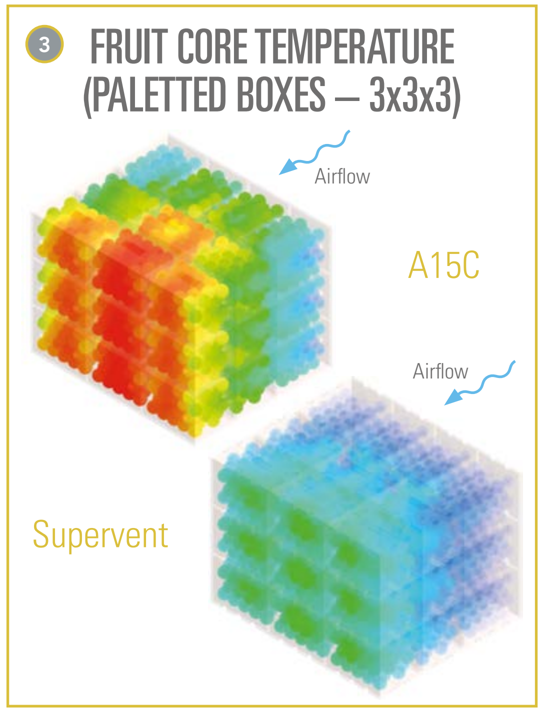
"We found that the percentage of vent area was the design parameter that had the biggest impact on airflow and produce cooling characteristics," says Prof. Opara. "It emerged that vents should take up about 7% of the box area for optimal and uniform airflow and cooling rate. Interestingly, we found that a 7% vent area also ensures the mechanical integrity of the packaging."

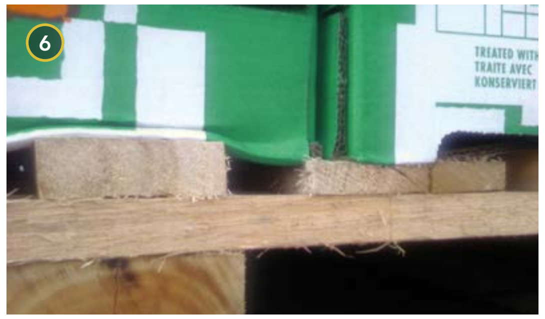
POSITIVE RESULTS

The research team successfully developed and validated mathematical models to predict the cooling performance of various fruit packaging solutions. This was used to formulate optimum package design and stacking parameters. They have put together a final model and developed practical guidelines to optimise packaging design for the South African fruit industry in future.

The benefits of this project are numerous and far-reaching. The researchers and post-graduate students who participated acquired valuable new skills in predictive packaging design and performance testing. This broadens their employment options and gives South Africa a competitive edge in packaging design internationally.

Furthermore, packaging solutions that reduce the incidence of fruit losses and financial claims will promote the reputation of the South African fresh fruit industry, leading to increased global competitiveness.





1 Some members of the packaging research team. Front (from left) Willem Gruyters, Dr Pankaj Pathare, Elrika Harmzeen and Karen Munhuweyi. Back (from left) Tobi Fadiji, Banji Oluwole, Tarl Berry, Dr Femi Caleb and Prof. Linus Opara.

2 The vent holes of boxes stacked onto a pallet need to align in order to allow optimal airflow to cool down the fruit. In this instance, the Sun Valley box design is ineffective.

3 This visualisation of heat transfer shows that fruit packed in Supervent cartons cools faster and more uniformly than those in standard A15C cartons.

4-5 What happens inside a single box of fruit is entirely different to what happens to boxes stacked on pallets inside a container being shipped overseas. The transfer of heat, airflow and moisture inside each box and the container as a whole, greatly influences final fruit quality.

6 Inadequate carton design, stacking and palletisation can result in mechanical damage of the carton and fruit, resulting in financial losses.