ETH zürich

Coop Research Program

Eco-smart ventilated packaging for fresh fruit using virtual cold chains

Fresh fruits from overseas are increasingly common in supermarkets. Their transport and storage require energy-intensive refrigeration to preserve fruit quality. This project assessed the refrigerated export pathway of citrus from South Africa to Europe, using a new modeling method, a life cycle assessment, and a full-scale experiment. Researchers found that packaging design and cooling schemes affect fruit quality and the carbon footprint of the supply chain.

Motivation

Cooling down fresh fruit after harvest and keeping it cool during transport and storage is essential to preserve fruit quality. This refrigerated supply chain, also known as a cold chain, requires high energy consumption. A promising strategy to minimize both fruit quality reduction and energy consumption is improving packaging design and cooling schemes along the cold chain. Changes in package type or wrapping can lead to faster and more uniform cooling. Cooling schemes, the different combinations of temperature and airflow conditions during pre-cooling, transport, and storage, also affect cooling performance.

Objective

The overall research objective was to minimize fruit quality reduction and environmental impacts in the citrus export pathway from South Africa, the third largest exporter of fresh citrus fruit worldwide. The project combined physical modeling and supply chain evaluation tools to optimize ventilated packaging design and different cooling schemes. In addition, full-scale experiments were conducted to assess real cooling performance in commercial facilities.

Research Highlights

The results show that the position of individual fruits within a carton and the applied cooling scheme affect fruit quality changes along the export pathway. The team of researchers developed a new modeling method, the virtual cold chain (VCC), to predict temperature and the quality evolution of each individual fruit in an entire pallet (up to 80 cartons and 5120 fruits) throughout the entire cold chain (see figure). VCC is based on computational fluid dynamics and kinetic quality modeling. Depending where individual fruits are located within a carton, quality loss can vary by up to 11%. The quality of the fruit that the consumer buys will thus depend on from where in the carton they choose the fruit. Cooling schemes also affected fruit quality. Quality loss was

Project members Dr. Wentao Wu, Philippe Häller, and Prof. Thijs Defraeye visiting a fruit storage facility.

World Food System Center

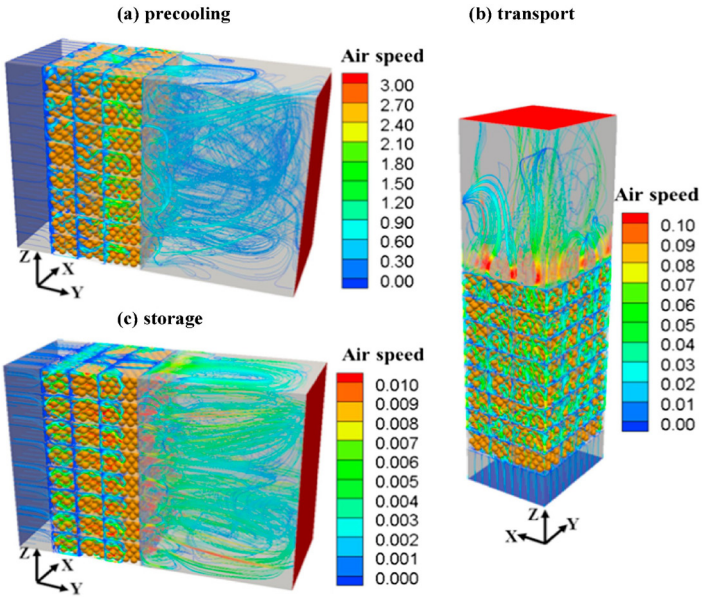
up to 23% larger in a cooling scheme without pre-cooling than with pre-cooling before transport.

Trade-offs between fruit quality and environmental impacts were quantified by combining VCC with a life cycle assessment of the entire supply chain, from agricultural production to retail. Surprisingly, cooling schemes with and without pre-cooling before transport had similar carbon footprints. However, the ambient loading scheme, where fruits are not cooled before shipment but entirely in the shipping container, preserved fruit quality better than the ambient cooling scheme, where fruits are cooled in a large cold room before shipment.

In commercial pre-cooling facilities, a full-scale experiment, using temperature sensors to measure fruit pulp temperature during commercial operations, showed that fruits cool faster if they are not wrapped and packed in cartons with the top side fully open (Opentop).

Relevance to Stakeholders

Project partners in South Africa are currently exploring ways to implement the tested ambient loading cooling scheme in regions with insufficient pre-cooling facilities. This scheme does not require pre-cooling but preserves fruit quality. In addition, technical guidelines for pre-cooling of citrus fruit are now publicly available. Fruit exporters gained relevant evidence-based information on the best cooling schemes and type of package to preserve fruit quality and reduce carbon footprint.



Simulation results show the airflow through a pallet (up to 80 cartons and 5120 oranges) during pre-cooling, transport and storage in the cold chain (Source: Wu, W; Defraeye, T. 2018).

Selected Publications

Wu, W.; Cronjé , P.; et al. Virtual cold chain method to model the postharvest temperature history and quality evolution of fresh fruit – A case study for citrus fruit packed in a single carton. *Comput. Electron. Agri.* **2018**,144, 199-208.

Wu, W.; Defraeye, T. Identifying heterogeneities in cooling and quality evolution for a pallet of packed fresh fruit by using virtual cold chains. *Appl. Therm. Eng.* **2018**, 133, 407-417.

Wu, W.; Häller, P.; et al. Full-scale experiments in forced-air precoolers for citrus fruit: impact of packaging design and fruit size on cooling rate and heterogeneity. *Biosyst. Eng.* **2018**, 169, 115-125.

Technical Guidelines

McGlashan, J.; Cronjé, P.; et al. *Guidelines for pre-cooling of citrus fruit for in-transit cold treatment in containers;* Citrus Research International Ltd., South Africa, **2016**.

Media

Bättig, R. Clever! Umweltfreundlich verpackt. *Coopzeitung*, **March 2016**, 10-11.

Workshops

New cold-chain and packaging technologies. ETH Zurich, Zurich, 28 August 2017.

Principal Investigator Prof. Thijs Defraeye, Empa

Co-Investigators Prof. Stefanie Hellweg, Prof. Jan Carmeliet

Postdoctoral Researcher Dr. Wentao Wu

Project Staff Claudio Beretta

Partners University of Stellenbosch, Citrus Research International, Sunday River Citrus

Project Duration 2015-2017

Funding WFSC Coop Research Program

Food System Challenges Addressed Sustainable packaging solutions, food value chain optimization

www.worldfoodsystem.ethz.ch/research/research-programs/CRP/pack.html

The WFSC would like to thank the Coop Sustainability Fund and the ETH Zurich Foundation for supporting this project.