Title Modeling the forced-air cooling process of fresh horticultural products

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Abstract

Optimal design and efficiency of the forced-air cooling process is vital to minimize postharvest losses of fresh strawberry packages. The intricate geometry of the package system and the large number of operating parameters have limited the optimization of this process.

The goal of this research is to develop and validate a mathematical model capable of predicting the airflow and energy transport during forced-air cooling applications. The fluid flow within the system was modeled by the steady state Navier-Stokes equations. The energy model considered the convective heat transfer between the strawberries and the bulk of air, and the removal of latent heat associated with the loss of fruit moisture. The model was solved within a typical strawberry package system by using a computational fluid dynamics solver.

The flow model was validated using non-intrusive Particle Image Velocimetry measurements. Minor differences between the predicted and experimental velocity fields were explained by considering the limits of the experimental uncertainty.

The energy model was validated by comparing the experimental and predicted temperature profiles of packed strawberries during two hours of cooling. The differences between the profiles of the average fruit temperature per package were always within the limits of the experimental error.

The results provide a fundamental understanding of the transport phenomena within the package system. Due to differences in the shape of packages and trays, (77 ± 2)% of the total amount of airflow bypassed the packages. Furthermore, (46 ± 5)% of the total mass flow rate forced through individual packages bypassed the strawberries. This significant bypass was due to the combined effect of a headspace on top of the fruits and the location of vents in the package walls. After one hour of cooling, the average-fruit-temperature per clamshell ranged from 2.4°C to 8.3°C between the first and last packages along the main flow direction. Within these packages, the maximum differences in the volume-average temperature of individual fruits reached 3.5°C and 5.1°C, respectively.

This research shows the potential use of this numerical approach as a design tool to optimize the forced-air cooling process of horticultural products.