Title Mathematical Modeling of Airflow, Heat and Mass Transfer during Forced Convection Cooling of Produce in Ventilated Packages

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Abstract

Forced convection cooling process is the most widely used method of cooling to extend shelf life of horticultural produce after harvest. However, heterogeneous cooling of produce inside different parts of ventilated packages is a serious problem. Therefore, it is essential to design packages that facilitate air circulation throughout the entire package to provide uniform cooling. Selection of appropriate combinations of air temperature and velocity for a given vent design is currently done largely by experimental trial and error approach. A more logical approach in designing new packages, to provide uniform cooling, is to develop mathematical models that would be able to predict package performance without requiring costly experiments.

In this study, mathematical models of simultaneous airflow, heat and mass transfer during forced convection cooling process were developed and validated with experimental data. The study showed that produce cooling is strongly influenced by different ventilated package designs. Generally, cooling uniformity was increased by increasing number of vents from 1 (2.4% vent area) to 5 (12.1% vent area). More uniform produce cooling was obtained at less cooling time when vents were uniformly distributed on package walls with at least 4.8% opening areas. Aerodynamic studies showed that heterogeneity of airflow distribution during the process is strongly influenced by different package vent configurations. The highest cooling heterogeneity index (108%) was recorded at 2.4% vent area whereas lowest heterogeneity index (0%) was detected in a package with 12.1% vent area.

The magnitudes of produce evaporative cooling (EC) and heat generation by respiration (HG) as well as the interactive effects of EC, HG and package vent design on produce cooling time were also investigated. Considerable differences in cooling times were obtained with regard to independent and simultaneous effects of EC and HG in different package vent configurations. Cooling time was increased to about 47% in a package with 1 vent compared to packages with 3 and 5 vents considering simultaneous effects of EC and HG. Therefore, the effects of EC and HG can be influential in designing the forced-air

precooling system and consequently, in the accurate determination of cooling time and the corresponding refrigeration load.