Fresh Produce Safety During Hydrocooling: An Engineering Model

A. Warning[1], A. K. Datta[1]

[1]Department of Biological & Environmental Engineering, Cornell University, Ithaca, NY, USA

Abstract

Introduction:
Hydrocooling is the process by which warm produce is chilled with water. The chilling of warm produce generates a negative pressure differential between the produce (warm) and (cold) water due to the condensation of water vapor inside the produce which forms a vacuum and can pull in water through an opening (Figure 1). Water contaminated with pathogenic bacteria can then infiltrate the surface through openings such as stem scars, wounds, or stomata. While experiments in literature have shown that this mechanism is positively correlated with contamination, other experiments have shown it may not be the only cause (Eblen et al., 2004; Richards and Beuchat, 2004). This model is the first physics based understanding of the hydrocooling problem in food safety.

Use of COMSOL Multiphysics®:
MRI was used to acquire images of a tomato which were segregated and imported into COMSOL Multiphysics® software as a 3D geometry with four domains. To reduce computation time, only a wedge was used because of symmetry. Then, heat transfer in fluids, Darcy's equation, transport of diluted species and transport of concentrated species were implemented in a porous media framework on the geometry with non-equilibrium condensation (Figure 2).

Results:
Figure 3 shows example results for temperature, pressure, and water for a 30°C temperature differential. The results show the temperature differential increases water uptake, but less than 1% (Figure 4). A lower initial moisture content and higher heat transfer rate further increase water uptake (results not shown). Other important model results reveal when the transition between diffusion and convective transport of water occurs (data not shown).

Conclusion:
A physics based model to give quantitative predictions of water infiltration of fresh produce was developed using an actual geometry acquired from MRI. Results were validated versus temperature and moisture. These results are the first physics based analysis of a major food safety problem. The model results give a quantitative guide to fresh produce handlers to mitigate a food safety problem. Overall, the results show that temperature differential is not the only main cause of infiltration but process (heat transfer rate) and product parameters (porosity, initial moisture content, and permeability) also significantly affect infiltration.

Reference

B.S. Eblen, et al., 2004. Potential for Internalization, Growth, and Survival of Salmonella and Escherichia Coli o157: H7 in oranges. Journal of Food Protection 67, 1578-1584.

G.M. Richards, L.R. Beuchat, 2004. Attachment of Salmonella Poona to Cantaloupe Rind and Stem Scar Tissues as Detected by Temperature of Fruit and Inoculum. Journal of Food Protection 1359-1364.

Figures used in the abstract

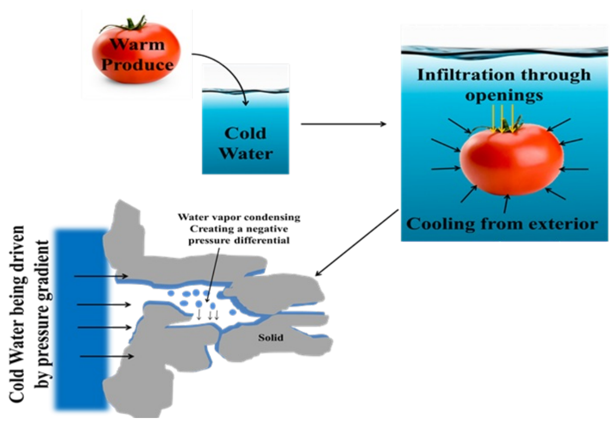

Figure 1: Schematic of hydrocooling process.

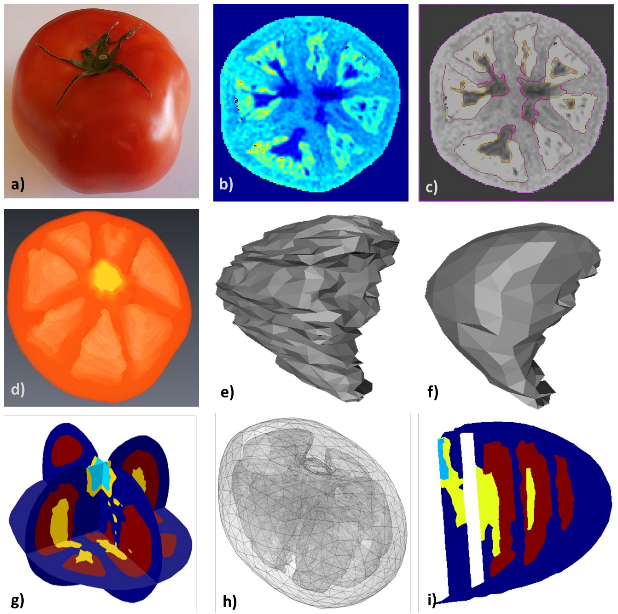

Figure 2: Images of a) tomato; b) T2 map of tomato, c) segregated slice, d) segregated slices combined to form whole tomato, e) example locular tissue after whole geometry has been reduced to 18000 faces, f) smoothed and reduced number of faces of locular tissue, g) planes cutting final geometry, where each color represents a different region, h) complete geometry in COMSOL, and i) scaled wedge used in simulations.

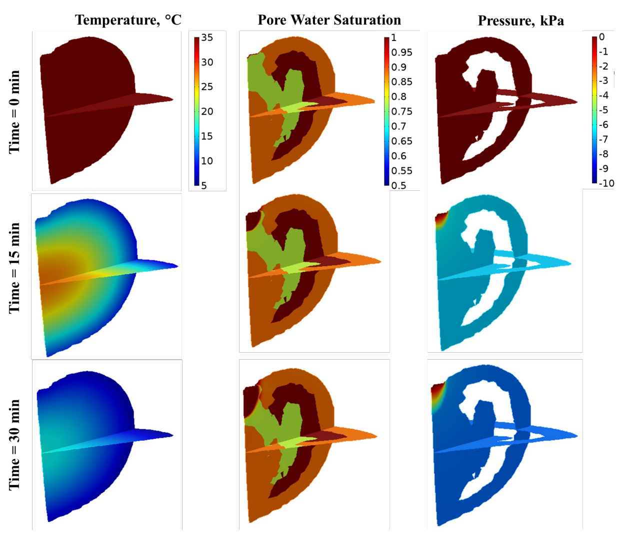

Figure 3: Spatial variation in tomato wedge of temperature (left column), pore water saturation (middle column) and pressure (column) at three different times. The initial temperature is 35°C and the water temperature is 5°C.

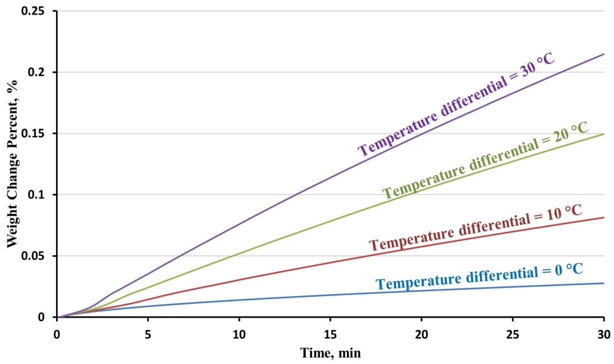

Figure 4: Simulation results for percent change in weight with time at four different temperature differentials.