Improving Heating Uniformity of Dried Fruit in RF Treatments for Pest Control: Model Development and Validation

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Abstract

Non-uniform heating is one of the most important challenges during the development of radio frequency (RF) heat treatments for pest control and other applications. A computer simulation model using finite element-based COMSOL Multiphysics® software was developed to investigate the heating uniformity of raisins packed in a rectangular plastic container (25.5 x 15.0 x 10.0 cm^3) and treated in a 6 kW, 27.12 MHz RF system. The developed model was then experimentally validated. Simulated and experimental temperature distributions in raisins after RF heating were compared in three different horizontal layers (top, middle, and bottom) within the container. Simulated and experimental average and standard deviation of the temperature values were highest in the middle layer, followed by the top and bottom layers. A sensitivity study indicated that the heating uniformity of the samples was most affected by the density of the raisins followed by the top electrode voltage, the dielectric properties, the thermal conductivity and the heat transfer coefficient. Corners and edges were heated more than the centers in each layer of the RF treated raisins. The model developed here can be used for future investigations to improve the heating uniformity for insect disinfection of dried fruit and other similar applications.

Figures used in the abstract

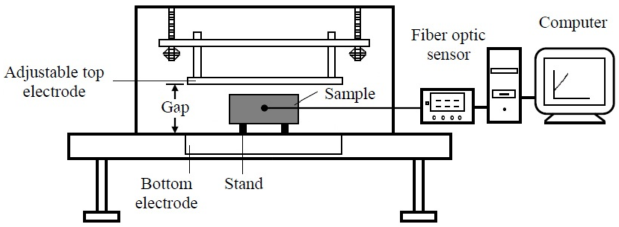

Figure 1: Schematic view of the pilot-scale 6 kW, 27.12 MHz RF unit showing the rectangular plastic container placed in between the top and bottom electrodes (Adapted from Wang et al., 2010).

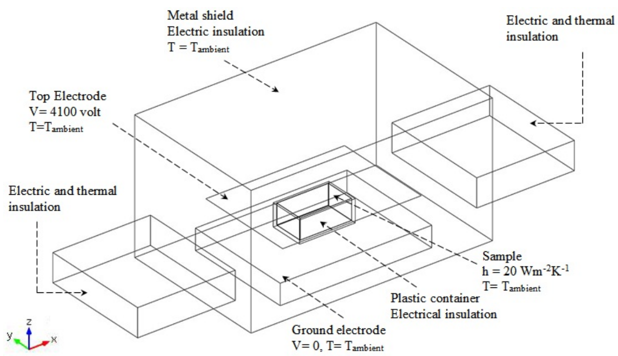

Figure 2: Geometrical, thermal and electrical boundary conditions of the 6 kW, 27.12 MHz RF system used in simulation.

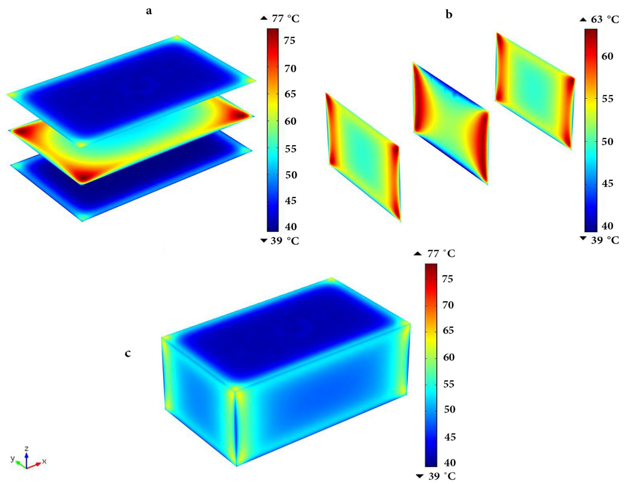

Figure 3: Simulated (LLLE x Kopelman) temperature (°C) profiles of raisins sample (25.5 L × 15.0 W × 10.0 H cm3) at (a) three horizontal layers (0, 5, and 10 cm), (b) three vertical layers (0, 12.8, and 25.5 cm), and (c) whole sample after 4 min RF heating with an electrode gap of 13.6 cm and initial temperature of 23 °C.

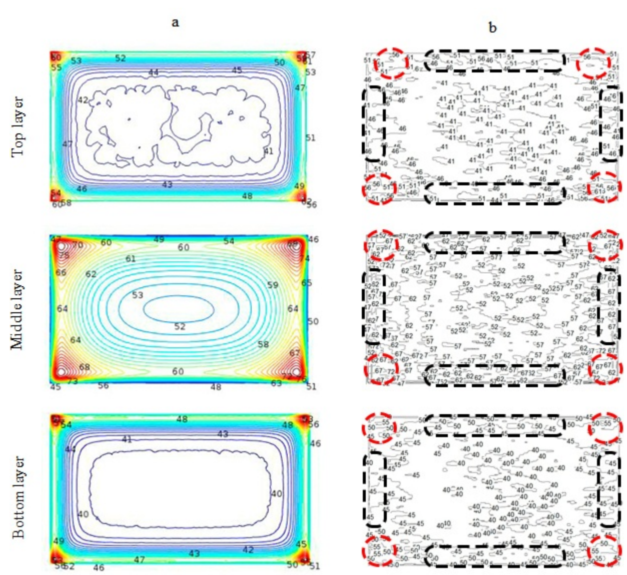

Figure 4: Simulated (LLLE x Kopelman) (a) and experimental (b) temperature distributions of top, middle, and bottom layers of raisin samples placed in a polypropylene container (25.5 L × 15.0 W × 10.0 H cm3) in the center and middle between the top and bottom electrodes of the RF system after 4 min heating at a fixed electrode gap of 13.6 cm and initial temperature 23 °C (Dash line areas have higher temperatures compared to other areas).