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

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Introduction: 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. The objective of this study was to investigate RF heating behavior in raisins using computer simulation with experimental validation.

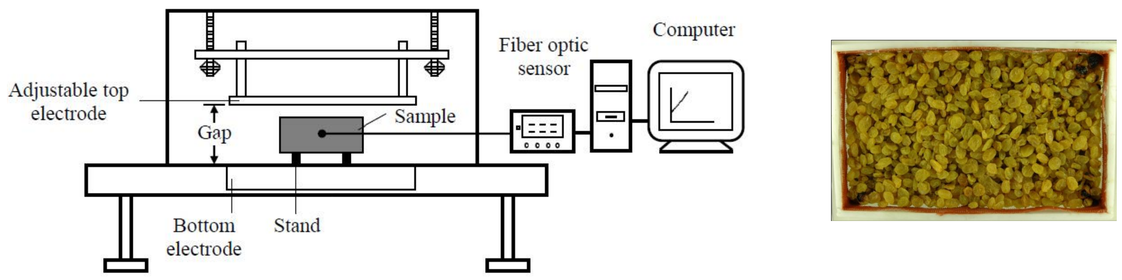

Figure 1. The 6 kW, 27.12 MHz RF unit and the rectangular plastic container placed in between the top and bottom electrodes (Notice the overheating-burning in the corners of the samples).

Computational Methods: A computer simulation model using COMSOL Multiphysics® software was developed to investigate the heating uniformity of raisins in a rectangular container (25.5x15x10 cm^3) and treated using RF heating. The following solution to the coupled quasi-static EM field and Fourier heat transfer equations were used to describe the heating pattern of a material (Choi, C. T. M. & Konrad, 1991):

$$\rho C_P \frac{\partial T}{\partial t} = \nabla(k\nabla T) + 2\pi f \varepsilon_0 \varepsilon'' E^2$$

Fig. 2 shows the boundary conditions of the RF system considered in the simulation.

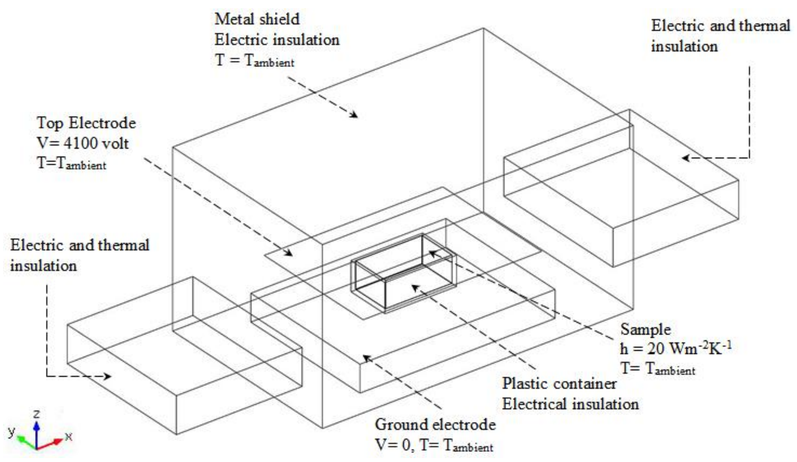

Figure 2. Geometrical, thermal and electrical boundary conditions of the RF system used in simulation.

Results:

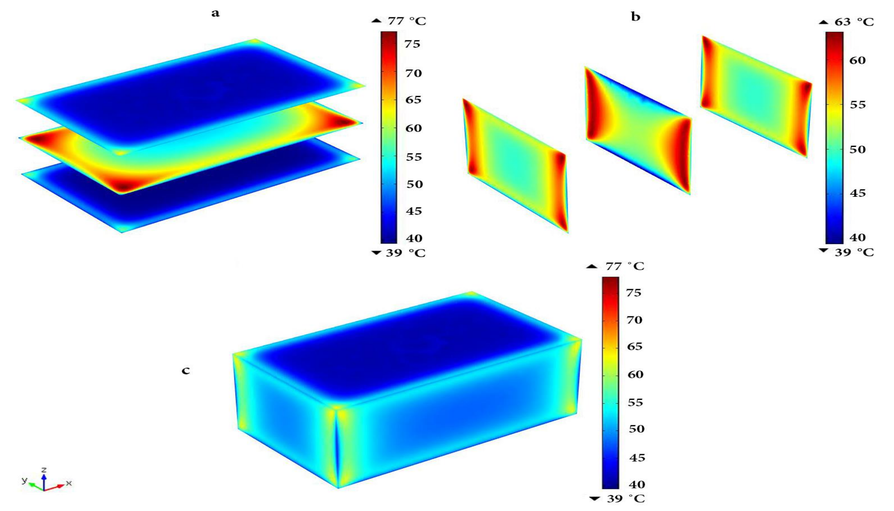

Figure 3. Simulated temperature (° C) of raisins at (a) three horizontal layers, (b) three vertical layers, and (c) whole sample after 4 min RF heating with a gap of 13.6 cm and initial temperature of 23 ° C.

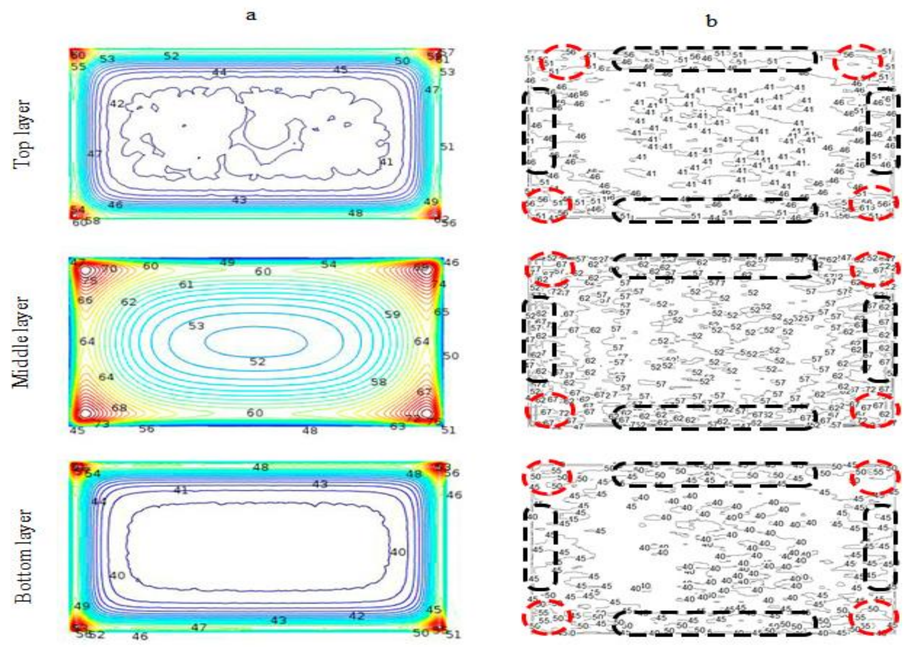

Figure 4. Simulated (a) and experimental (b) temperature distributions of three horizontal layers of after 4 min RF heating at 13.6 cm gap.

Conclusions: The simulated and the experimental results showed higher temperatures in the middle layers compared with those of the top and the bottom layers. Corners and edges were heated more than center areas in all layers. This model can be used to investigate the effect of electrodes and sample shape on the heating uniformity.

References:

Choi, C. T. M. & Konrad, A., Finite-element modeling of the RF heating process, IEEE Transactions on Magnetics, 27(5), 4227–4230 (1991).

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