3-Dimensional Numerical Modeling of Radio Frequency Selective Heating of Insects in Soybeans

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Abstract

Radio frequency (RF) heating have potential as alternatives to chemical fumigation for disinfesting legumes. This study was conducted to investigate the feasibility of RF selective heating of insect larvae in 3 kg soybeans packed in a rectangular plastic container using a 6 kW, 27.12 MHz RF heating system. A finite element based computer simulation program-COMSOL Multiphysics was used to solve the coupled electromagnetic and heat transfer equations (Joule heating model) for developing a simulation model. Indianmeal moth larvae were selected as the target insect for experimental validation of the simulation results. Simulated and experimental temperatures of insects and soybeans after 6 min RF heating were compared in top, middle, and bottom layers within the container. Both results showed that insect larvae were differentially heated with 5.9-6.6 °C higher than host soybeans when RF heated from 25 to 50 °C. These results revealed that the heating rate of insects was 1.4 times greater than that of soybeans. The validated simulation results demonstrated that placing the insect on the cold spot of each layer, or horizontally, and large insect size may cause less selective heating within the insect bodies. Dielectric properties of insects may also influence the preferential heating patterns. The selective heating of insects in soybeans may provide potential benefits in developing practical RF treatments to ensure reliable control of insect pests without adverse effects on product quality.

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Figures used in the abstract

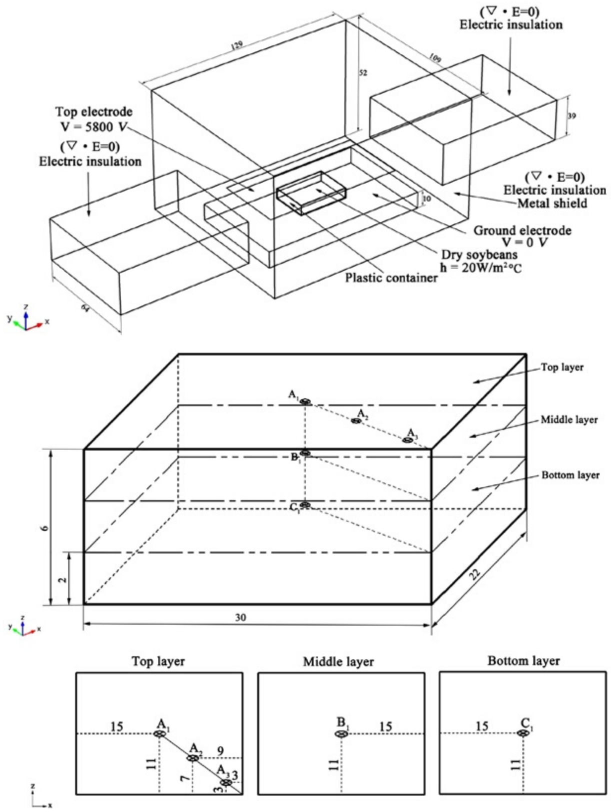

Figure 1: Boundary and initial conditions for the RF system used in the computer simulation model (all dimensions are in cm).

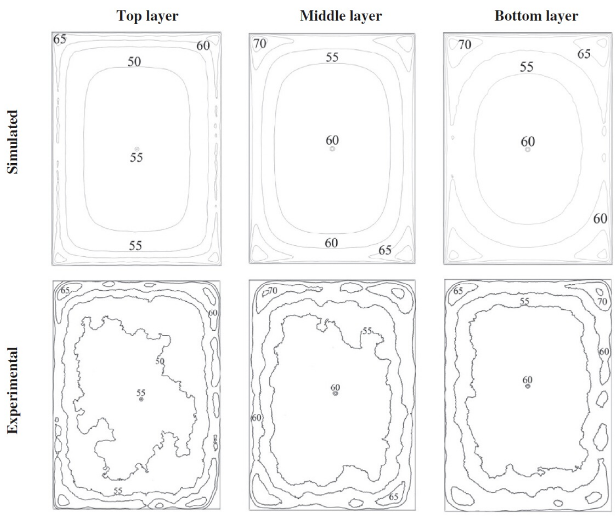

Figure 2: Comparison of simulated and experimental temperatures for top, middle, and bottom layers of dry soybeans and three insects at the geometric center of each layers (2, 4, and 6 cm from the bottom of sample), placed in a polypropylene container.

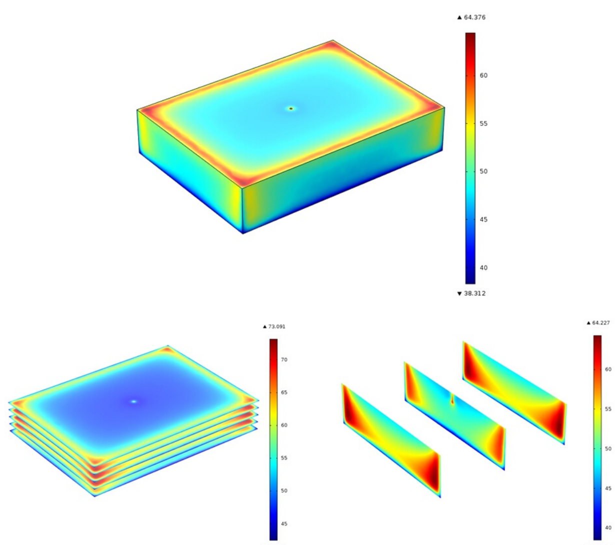

Figure 3: Simulated temperature (°C) profiles of dry soybeans at each layers after 6 min RF heating with an electrode gap of 120 mm and initial temperature of 25 °C .

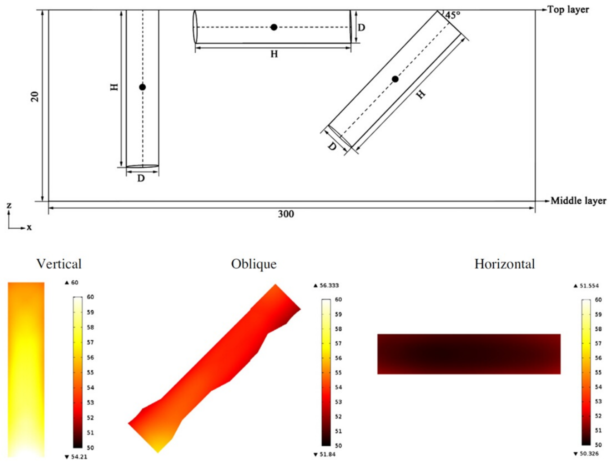

Figure 4: Computer simulated temperature (°C) distribution of insects along the central cross-sectional with three different placements (vertical, oblique and horizontal) located at the top surface center of soybeans under the same RF heating conditions.