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Heat Transfer Modeling of 'Carabao' Mango (Mangifera indica L.) during Postharvest Hot Water Treatments

Authors : Hazel James P. Agngarayngay, Arnold R. Elepaño

Abstract : Mango is the third most important export fruit in the Philippines. Despite the expanding mango trade in world market, problems on postharvest losses caused by pests and diseases are still prevalent. Many disease control and pest disinfestation methods have been studied and adopted. Heat treatment is necessary to eliminate pests and diseases to be able to pass the quarantine requirements of importing countries. During heat treatments, temperature and time are critical because fruits can easily be damaged by over-exposure to heat. Modeling the process enables researchers and engineers to study the behaviour of temperature distribution within the fruit over time. Understanding physical processes through modeling and simulation also saves time and resources because of reduced experimentation. This research aimed to simulate the heat transfer mechanism and predict the temperature distribution in ‘Carabao' mangoes during hot water treatment (HWT) and extended hot water treatment (EHWT). The simulation was performed in ANSYS CFD Software, using ANSYS CFX Solver. The simulation process involved model creation, mesh generation, defining the physics of the model, solving the problem, and visualizing the results. Boundary conditions consisted of the convective heat transfer coefficient and a constant free stream temperature. The three-dimensional energy equation for transient conditions was numerically solved to obtain heat flux and transient temperature values. The solver utilized finite volume method of discretization. To validate the simulation, actual data were obtained through experiment. The goodness of fit was evaluated using mean temperature difference (MTD). Also, t-test was used to detect significant differences between the data sets. Results showed that the simulations were able to estimate temperatures accurately with MTD of 0.50 and 0.69 °C for the HWT and EHWT, respectively. This indicates good agreement between the simulated and actual temperature values. The data included in the analysis were taken at different locations of probe punctures within the fruit. Moreover, t-tests showed no significant differences between the two data sets. Maximum heat fluxes obtained at the beginning of the treatments were 394.15 and 262.77 J.s-1 for HWT and EHWT, respectively. These values decreased abruptly at the first 10 seconds and gradual decrease was observed thereafter. Data on heat flux is necessary in the design of heaters. If underestimated, the heating component of a certain machine will not be able to provide enough heat required by certain operations. Otherwise, over-estimation will result in wasting of energy and resources. This study demonstrated that the simulation was able to estimate temperatures accurately. Thus, it can be used to evaluate the influence of various treatment conditions on the temperature-time history in mangoes. When combined with information on insect mortality and quality degradation kinetics, it could predict the efficacy of a particular treatment and guide appropriate selection of treatment conditions. The effect of various parameters on heat transfer rates, such as the boundary and initial conditions as well as the thermal properties of the material, can be systematically studied without performing experiments. Furthermore, the use of ANSYS software in modeling and simulation can be explored in modeling various systems and processes.

Keywords : heat transfer, heat treatment, mango, modeling and simulation
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