Title 3-D microscale modelling of gas diffusion in fruit tissue

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Abstract

Gas diffusion properties of pear tissue are important to the gas exchange during storage of the fruit. The O_2 transport was modelled using diffusion laws, irreversible thermodynamics and solved on the 3-D microscopic geometry of the fruit using the finite volume method. The 3-D microstructure of pear tissue was obtained by synchrotron radiation X-ray tomography. The pores and the cells were distinguished by a binary variable in each voxel of the 3-D cubic sample image of tissue. Physical transport properties of oxygen in gas and water were assigned to the pores and cells, respectively, while the resistances of the cell wall and the cell membrane were taken into account at the interface between gas and liquid phases by an effective permeability value. 3-D O_2 transport was simulated in different types of pear tissue. Simulation results showed that the O_2 transport was conducted mainly by means of the intercellular space and less through the intracellular liquid. The epidermis and sub-epidermis layers of pear are a strong barrier to diffusion. The parenchyma tissue that displayed a high connectivity of the void network had high oxygen diffusivity. The characteristic brachysclereids (stone cells) that appear frequently in pear fruit cortex have a large effect on the pore network distribution, resulting in an increased barrier to diffusion. The simulated diffusivity values of epidermis and subepidermis were comparable to measurement values while a discrepancy between the simulated and measured O_2 diffusivities in the parenchyma cortex tissue was found. 3-D microscale simulation of cortex tissue showed a larger diffusivity than the measurement. Structural changes and heterogeneity of tissues are related to imbalances in gas exchange that may eventually lead to cell death at a certain storage condition.