Title A 3-D virtual pome fruit tissue generation based on cell growth modeling

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Abstract

The microstructure of fruit determines its mechanical and transport properties of tissues. The cellular architecture is established during the growth of the fruit. Understanding the development and the changes of the microstructure of fruits would be an important step to explain and help to optimize fruit production and postharvest storage. The current pome fruit tissue generators are based on digitized 2-D or 3-D images of the cellular architecture, which require experimental input in terms of microscopic images. Recently, a virtual tissue code was developed that generates 2-D virtual pome fruit tissues based on a cell growth model. Although it is able to generate representative 2-D pome fruit tissues, many biophysical models for phenomena such as gas transport during postharvest storage require that the 3-D microstructure is resolved especially with regards to the intercellular air space network. To this end, a 3-D cell growthbased algorithm is being developed using the biomechanics of plant cells in tissues considering typical differences in intercellular air space networks, cell size and shape found between different fruit species and cultivars. The cell is considered as a closed thin walled structure, maintained in tension by turgor pressure. The cell walls of adjacent cells are modeled as parallel and linearly elastic elements which obey Hooke's law. A 3-D Voronoi tessellation is used to generate the initial topology of the cells. Intercellular air spaces of schizogenous origin are generated by separating the Voronoi cells along the edges where three Voronoi cells are in contact while intercellular air spaces oflysigenous origin are generated by deleting (killing) some of the Voronoi cells randomly. Cell expansion then results from turgor pressure acting on the yielding cell wall material. To find the sequence of positions of each vertex and thus the shape of the tissue with time, a system of differential equations for the positions and velocities of each vertex are established and solved using a Matlab ODE solver. Comparison is made with fruit tissue synchrotron tomography images. The virtual tissues can be used to study tissue mechanics and exchange processes of important metabolites.