Micro-Scale Numerical Simulation of Water Migration in Plant-Based Materials During Isothermal Drying

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The isothermal drying of plant-based material, such as fruits and vegetables, is the most widely used drying technique to stabilize materiel and to increase their shelf life. However, drying is a high energy-consuming industry process, in which water removal obviously affects the quality of dried products. Therefore, it is crucial to understand the water migration mechanisms during drying for improving energy efficiency and ensuring better quality.

Plant-based material generally has highly porous characteristics, and the major part of the water (about 80-90%) is present in the intracellular space, but not in the intercellular (pore) space. There are three pathways for water moving out from the cell: cell-to-cell, wall-to-wall, and intercellular transport. To better understand the water migration, a micro-scale numerical simulation method is proposed in this paper. In the presented method, the mathematical models of the three pathway are developed separately, then coupled through the mass flux, such as the flux of cell membrane.

Based on COMSOL software, the water migration of cellular tissues of potatoes is simulated under isothermal drying conditions. It can be seen from the numerical results: (1) The permeability of the cell membrane has a large influence on the macroscopic water conductivity of a tissue, and the gradients of water content is maximum at the face between cell membrane and cell wall. (2) In the early stage of drying, the water content of plant materials is relatively high, and the water potential distribution of each cellular environments can be regarded as a balanced distribution; while in the late stage of drying, the water content of plant materials decreases and the equilibrium state no longer exists.

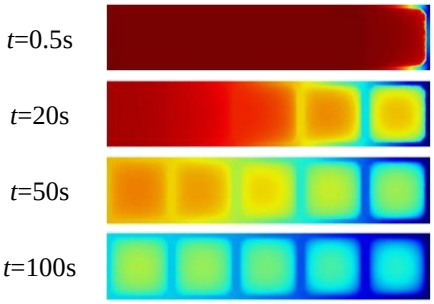

Figure 1: Water potential distribution in central section of cell string

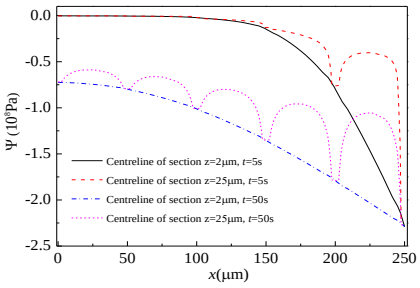

Figure 2: Distribution of water potential along the centreline

Keywords: Isothermal drying; Plant materials; water migration; micro-scale numerical simulation

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