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Simulation of Salt Diffusion Process into Leafy Vegetables during Cooking

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Summary

During cooking, salt concentrations in the soup and food ingredients fluctuate due to the diffusion of salt from the soup and the evaporation of water. Understanding the changes in salt concentration in cooked food is crucial for setting appropriate seasoning conditions. When Chinese cabbage is cooked in soy sauce solution, the cut surface tends to darken, suggesting that the pigments from the soy sauce may primarily diffuse from the cut surface. Yet, no studies have compared the salt diffusion rates between the cut and uncut surfaces of food. This study aims to simulate the salt diffusion process in Chinese cabbage during cooking by measuring the diffusion coefficient (D) and mass transfer coefficients for cut (hc) and uncut (hu) surfaces.

The experimental setup involved soaking Chinese cabbage in a 0.20-M NaCl solution at 5°C–80°C. After soaking, the cabbage was divided into two parts—the outer 5 mm and the inner part—and salt concentrations in each part were measured. D was calculated to fit the experimental data using a 3D diffusion equation, with and without the mass transfer coefficients (hu and hc). For validation, the cabbage was boiled in a 0.17-M NaCl solution (equivalent to 1%) for 10 min and then maintained at 65°C for 2 h. Changes in the salt concentration of the solution and cabbage were measured and simulated using COMSOL Multiphysics, a finite element method-based software.

The simulation results revealed that the calculated salt concentrations for the inner part, determined without considering hu and hc, were higher than the experimental values. In contrast, the results obtained by including hu and hc were in good agreement with the experimental data for both parts. Notably, hu was found to be 10-11 times lower than hc, indicating that salt primarily diffuses through the cut surface. The temperature dependence of D and hu was expressed using the Arrhenius equation, which showed that hu did not vary with temperature. The agreement between the predicted and experimental changes in salt concentrations during cooking confirmed the validity of the simulation.