

## **Development of a closed-loop control system for microwave freeze-drying of carrot slices using a dynamic microwave logic control**

### **ABSTRACT**

This research aimed to develop a closed-loop control (CLC) system to improve the microwave freeze-drying (MFD) process and to examine the effects of a dynamic microwave logic control (DMLC) on the drying characteristics of MFD. The development process consisted of two parts: (1) the MFD experiment to develop the DMLC, and (2) the implementation of the CLC with the DMLC on the MFD process. In the first part, the MFD process was examined to obtain the strategy for drying the carrot slices using microwave powers of 100 W, 200 W, and 300 W, with a temperature profile of the sample from  $-15^{\circ}\text{C}$  to  $40^{\circ}\text{C}$ , and the final moisture content of 6% (wet basis). In the second part, the DMLC was strategically developed and integrated into the CLC system. The results showed that in the MFD process, the DMLC was developed based on a drying-phase configuration and dynamic control between the microwave power and real-time moisture content sensing to provide feedback to the CLC system. After applying the DMLC into the CLC system, the efficiency of the MFD process was improved by up to 62.4% by shortening the drying time, as compared with the freeze-dry (FD) process. The MFD-DMLC also resulted in the quality of carrot equivalent to that of a traditional FD process. Since the DMLC exhibited great potential to improve the MFD process, it could be developed for future industrial use for a high-performance MFD process in terms of product quality and process efficiency.

**Keyword:** Microwave freeze-drying; Closed-loop control system; Dynamic microwave logic control; Drying characteristics; Carrot slices