

Closed-loop temperature control during microwave freeze-drying of carrot slices

ABSTRACT

Temperature variations during microwave freeze-drying (MFD) of carrot slices and how closed-loop temperature control (CLT) improved such variations were investigated. The carrot slices were dried to a final moisture content of 6% with a terminal temperature of 40°C using 100-watt microwave power under 100-Pa vacuum pressure. The results showed that the MFD process consisted of two phases, viz. sublimation and desorption drying. In the sublimation drying phase, ice, due to its low dielectric permittivity, absorbed little microwave energy. This caused a slow rising of temperature of carrot slices at the early stage of drying. After the moisture decreased below 45%, the sample temperature increased sharply until it reached the temperature of the chamber, indicating the onset of desorption drying phase. In this phase, the sample temperature rose faster than that in the sublimation phase. Without CLT, the temperature of carrot slices varied by 25°C in the desorption drying phase of MFD. After applying CLT to the MFD process, the variation in temperature of the carrot slices was reduced to 11°C, equivalent to a temperature control improvement of 56%. The MFD with CLT system also significantly reduced the drying time and energy consumption by 35-40%.

Keyword: Carrot slices; Microwave freeze-drying; Sublimation; Desorption; Closed-loop temperature control