Mathematical Model of Vacuum Foam Drying

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Abstract

The mathematical model is closely related to the development of novel drying method for high viscous and sticky materials. The foamed state facilitates diffusive moisture transport and therefore accelerating the drying process. Moreover the dried porous material can be easily converted into the powder. The foam drying is coupled with vacuum drying technique in order to gently process heat and oxygen sensitive materials (e.g. tea extract, coffee extract, natural pigments, starter cultures, enzyme preparations).

The mathematical modelling aimed at evaluating the complex drying process as basic simultaneous heat and mass transport. The model should predict the time dependent temperature and moisture distribution in the product and the impact of product and process parameters. The model should provide optimal parameters for vacuum drying.

The mathematical model consists of fully coupled heat and mass transfer. Heat transfer was modelled with Fourier´s law. Considering closed-pore material structure the heat transfer consists of thermal conduction in liquid-condensed phase and evaporation/condensation in gas phase in air bubbles. The effective heat transfer coefficient through dried material was described in dependency on material structure, temperature and water content. The mass transfer was in similar manner divided into the vapor and liquid diffusion, considering their parallel arrangement. The mass transport was modelled using Fick´s law. The moisture diffusion was described in terms of effective diffusion coefficient. The formation of vapor partial pressure gradient has dominating impact on moisture movement. The vapor gradient is induced by a nonuniform temperature distribution as the material is heated from one side. For calculation of vapor gradient equilibrium condition was assumed. The vapor partial pressure over the foam liquid phase was calculated directly from spatial temperature. The dependency on moisture concentration was expressed by Guggenheim-Anderson-de Boer equation. The mathematical model was solved in COMSOL Multiphysics® software using finite element method. The validation of mathematical model was conducted with maltodextrin foams various porosity (Φ=0.68-0.9) dried at various temperature and absolute pressure. The results showed good agreement with the experimental data.