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Pore scale study of freeze-drying using a non-isothermal pore network model and X-ray tomography image data

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Freeze-drying is investigated based on a non-isothermal pore network model of coupled heat and mass transfer [1]. Simulations were carried out using image data from X-ray tomography (µ-CT) of freeze-dried maltodextrin, which was originally prepared with a solid content of c = 0.2 w/w solved in water [2]. Freeze-drying was conducted at a shelf temperature of -18℃ and a chamber pressure of 10 Pa [3]. The experimental parameters were used in the pore network simulation in which a domain size of 100x100x250 µm3 was considered. The pore network simulation provides data about the dynamics of the pore scale resolved sublimation front propagation as well as local temperature and pressure evolution and vapor diffusion rates. It can be shown and analyzed for the first time how the sublimation front travels through the pore network in dependence of pore size distribution and various different process conditions. For this purpose, different temperature and pressure conditions were applied at the boundaries of the pore network. Besides µ-CT image data, also regular pore networks with different pore size distributions (monomal and bimodal) were implemented. The latter option is faster than imaging and image processing and allows to study more fundamentally different scenarios. This way, the evolution of the sublimation front can be studied at the limits of i) heat and ii) mass transfer controlled freeze-drying regimes as well as intermediate situations. As a result, the conditions for the formation of either flat or structured sublimation fronts can be provided. The outcome of this study can thus be used as a base for the prediction of material collapse.

Participation

In-Person

References

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