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RESEARCH PAPER

Examination of thermo-physical and material property interactions in cereal foams by means of Boltzmann modeling techniques

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Abstract Cereal foam is a high complex material undergoing several temperature-dependent processes under thermal treatment, such as phase transitions, biochemical reactions and structural changes. Simultaneous heat and mass transfer plays an important role to investigate optimization studies in cereal-based foams. In porous media such as cereal foams, thermal conduction is of minor impact on the overall heat transfer, since the major part of heat is transferred through the gas phase filled with water vapor. This becomes evident comparing the thermal diffusivities of solid and gaseous components of the foam, where the difference is in the order of five magnitudes. The objective of this study is to model the coupled heat and mass diffusion processes in cereal-based foam under thermal treatment by means of Lattice Boltzmann methods. The proposed model is then used to perform parameter variation studies, showing the impact of material property changes offering the possibility on optimizing heat transfer through the foam.

Keywords Numerical modeling · Lattice Boltzmann · Simultaneous heat and mass transfer · Cereal foam

List of symbols

A	Thermal diffusion coefficient
Ω	Collision operator
τ	Relaxation time
eq	Equilibrium
f	Particle distribution function
v	Velocity
c	Lattice speed of sound
x	Space coordinate
e	Direction vector
w	Weight factor
ρ	Density
C	Concentration
Fo	Fourier number
L	Characteristic length
t	Time
D	Mass diffusion coefficient

1 Introduction

Numerical modeling of heat and mass diffusion inside foam is a quite challenging task due to the complexity of the structure and processes occurring in the micro-scale. Classical continuum mechanics are describing the flow as a continuum by solving the Navier–Stokes equations. Such methods are known as macro-scale methods. They offer a powerful tool to model fluid flow if only a continuum description of the process is required. If more detailed insight in the microphysics of the flow is the objective, such methods are not recommended, since they fail in for low Knudsen numbers (Hussein 2010). Comparatively, the LBM is a meso-scale method. The advantage of the LBM is that the macroscopic flow is modeled in the spatio-temporal range where the flow originally happens on the particle level. As further plus, the Navier–Stokes equations and therewith the macroscopic flow properties can be recovered from the LBM equations bridging micro and macro scales (Succi 2001).

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