Tech Science Press

ICCES, 2024, vol.31, no.3
DOI: 10.32604/icces.2024.012535

PROCEEDINGS

Numerical Study of Coupled Cilia and Mucus in Herschel-Bulkley Flows

Qian Mao[1], Umberto D'Ortona[1] and Julien Favier[1,*]

[1]Aix-Marseille University, CNRS, Centrale Med., M2P2, Marseille, 13013, France
[*]Corresponding Author: Julien Favier. Email: julien.favier@univ-amu.fr

ABSTRACT

The human airways are protected by two fluid layers, a periciliary layer (PCL) covering the epithelial surface and a mucus layer on top of the PCL. The cilia are almost immersed in the PCL and interact with the mucus through their tips. The mucus is often described as a yield stress and shear thinning fluid. The effect of these non-Newtonian properties on ciliary coordination and mucus transport was investigated using the Lattice-Boltzmann method. The non-Newtonian mucus was modelled using the Herschel-Bulkley model. Three mucus flow regimes were observed and analysed in a wide range of parameters, including ciliary density, interaction length, Bingham number (indicating the effect of yield stress) and flow index (indicating the effect of shear thinning). The characteristics of three flow regimes were revealed. Regime formation under different conditions was analysed in detail. A rescaling of the interaction length was proposed and the mucus viscosity was found to be the dominant parameter influencing the regime formation. The present model can reproduce the experimental observation more accurately than the previous Newtonian model. We improved the cilia-mucus model and elucidated several physical mechanisms underlying the transport of non-Newtonian mucus by cilia and the role of mucus viscosity, with the perspective of progressing in the understanding of mucociliary clearance in human lungs.

KEYWORDS

Lattice-Boltzmann method; pulmonary fluid mechanics; non-Newtonian flows; low-Reynolds-number flows

Acknowledgement: Centre de Calcul Intensif d'Aix-Marseille University is acknowledged for granting access to its high performance computing resources.

Funding Statement: This work was supported by the BonchoClogDrain project (ANR-22-CE30-0045) funded by the French National Research Agency (ANR).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.