Interfacial rheology of DPPC monolayers and its possible implications for membrane fluidity and lung surfactant rheology

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Abstract

Phospholipids are important lipids present in living organisms. They are the major constituents of vertebrate's lung surfactant as well as cell membranes. Characterizing the interfacial rheology of a DPPC monolayer could give a first indication on the fluidity or rheology of both systems.

In the case of lung surfactant, it prevents the alveoli from collapsing by lowering the surface tension, and reduces the energy necessary for breathing. However, this localized reduction in surface tension during exhaling would cause a flow from the alveoli towards the terminal bronchioles driven by a difference in surface tension (Marangoni effect). It has been suggested that the interfacial rheology limits this surfactant induced flow and may keep the lung surfactant in place[1]. However on the other hand, it is expected that the phospholipids maintain a low viscosity in the cell membrane so lipid rafts can move easily across the surface of the cell.

Techniques used in the past to characterize DPPC monolayers faced the problem of being dominated by subphase drag[2,3] for the physiological relevant conditions and the inherent sensitivity is limited. The use of a interfacial needle rheometer and ribbon trough with adapted Double Wall Ring accessory resolved these problems and allowed the characterization of DPPC monolayers for temperatures ranging from 20 to 37°C and surface pressures from 20 up to values as high as 60 mN/m.

The rheological behavior of the monolayer is observed to be similar to a general liquid predicted by Doolittle's equation[4]. The interfacial viscosity rises exponentially with increasing pressure and decreasing temperature and can be quantified by a change in free molecular area. At physiologically relevant conditions, low interfacial viscosities are detected. These results suggest that membranes will be quite fluid-like, but the role of interfacial rheology for lung surfactants might have to be reconsidered.

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