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Influence of silica nanoparticles on phase behavior and structural properties of DPPC—Palmitic acid Langmuir monolayers

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ABSTRACT

The effect of silica nanoparticles on the thermodynamic and structural properties of monolayers of 1,2-dipalmitoyl-sn-glycerol-3-phosphocholine (DPPC), palmitic acid (PA) and a mixture of them, has been investigated using a combination of Langmuir trough technique and Brewster Angle Microscopy (BAM). This study shows that the presence of nanoparticles in the aqueous sub-phase affects the surface pressure–area (Π–A) isotherm, leading to a different phase behavior of the monolayer. The observed effects are explained assuming the incorporation of nanoparticles into the monolayer driven by the adsorption of lipid molecules onto the silica which makes the nanoparticles more hydrophobic. This process hinders the ordering and affects the composition of the investigated lipid monolayers significantly modifying also their quasi-equilibrium dilational elasticity.

The reported results are useful in the framework of a wider study aimed at elucidating the impact of nanoparticles on the physico-chemical properties of pulmonary surfactant, being DPPC its major component and PA utilized as an important component in the formulation of therapeutic substitutes.

1. Introduction

Monolayers of fatty amphiphiles have been extensively investigated using Langmuir trough technique [1–4] which is an effective tool to access the phase behavior of this kind of systems. In fact, from the analysis of the area–surface pressure isotherms it is possible to gain information on the structural changes of the monolayer induced by molecular lateral packing [5,6]. More information about the structure of the monolayers can be obtained by X-ray diffraction technique, which is the most appropriate to study the lateral packing in the monolayer [7], and by other in situ optical techniques like Fluorescence Microscopy [8], Laser Light Scattering [9] or Brewster Angle Microscopy [10,11].

It is moreover of increasing interest to understand how the introduction of additional components, such as solid nanoparticles, changes the equilibrium and dynamic properties and the structure of these insoluble monolayers.

For example, the interaction of nanoparticles with lung surfactant and their impact on its behavior and structure is a relevant topic on which some results can be already found in literature [12,13]. The increasing interest on this topic is due to the wide spreading of nanosystems in various technological fields [14], which rises the need of evaluating their potential toxicity and hazards. Among them, most relevant is the effect on respiratory functionality, lungs being the major entry point for microscopic particulates [15,16].

The lung surfactant is a complex mixture containing 1,2-dipalmitoyl-sn-glycerol-3-phosphocholine (DPPC), as main component, unsaturated phosphatidylglycerols (PG) and phosphatidylcholines (PC), cholesterol and the surfactant-specific proteins B and C [17–19]. Additionally it is possible to find in lower proportion other surfactant-proteins (A and D) and other components such as palmitic acid (PA) which is also used as a component in lung surfactant substitute therapies [20,21]

It is also important to mention that the effect of the nanoparticles on the physico-chemical properties of liquid interfaces has been investigated in several works [22–26]. It has been shown that their surface segregation affects the thermodynamic and kinetic behavior of surfactant systems influencing the interfacial tension and the dilational rheology of the systems [24,25].

In the present work the interaction of silica nanoparticles with lipid monolayers is investigated from the thermodynamic and structural point of view, by using a Langmuir trough technique coupled with Brewster Angle Microscopy diagnostics. The investigated systems were, in particular, monolayer composed by DPPC and PA, spread on silica nanoparticle dispersions.

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