Mechanical properties of membranes composed of milk polar lipids in the gel or fluid-phase probed by AFM on liposomes

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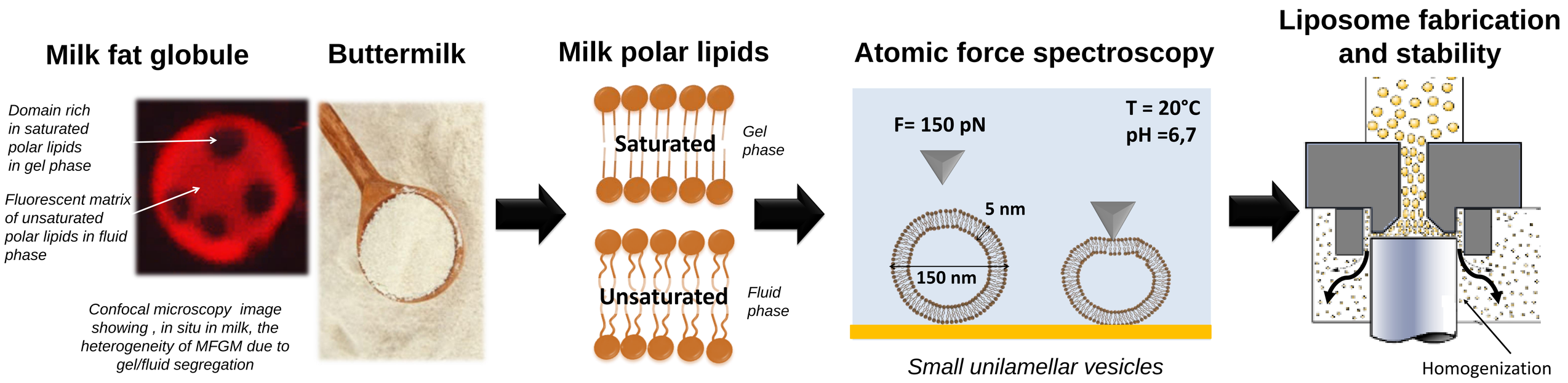
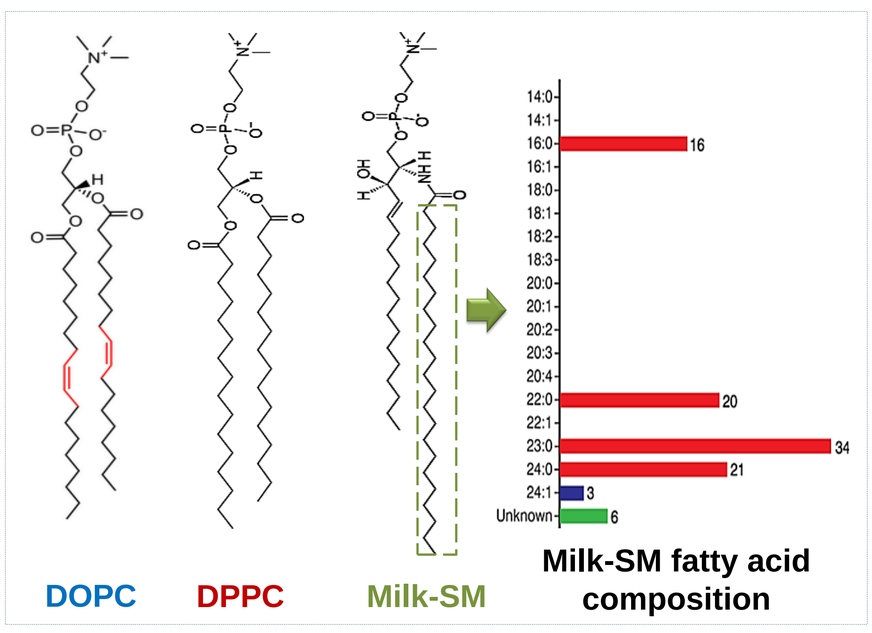
Milk polar lipids for liposome applications :

The milk fat globule membrane (MFGM) has recently gained a lot of attention, due to the growing interest in its nutritional and technological properties. Its composition, rich in polar lipids, has great potential for new product applications with unique physical properties such as liposomes. Milk polar lipids might be advantageous for both the stability and the biological acceptance of the formulation. Milk polar lipids possess different structures of molecules: saturated with high melting temperatures (Tm),in particular the milk sphingomyelin (SM,Tm 35°C); or unsaturated with low Tm. Does this difference in the molecular structure affect the mechanical properties of the membranes?



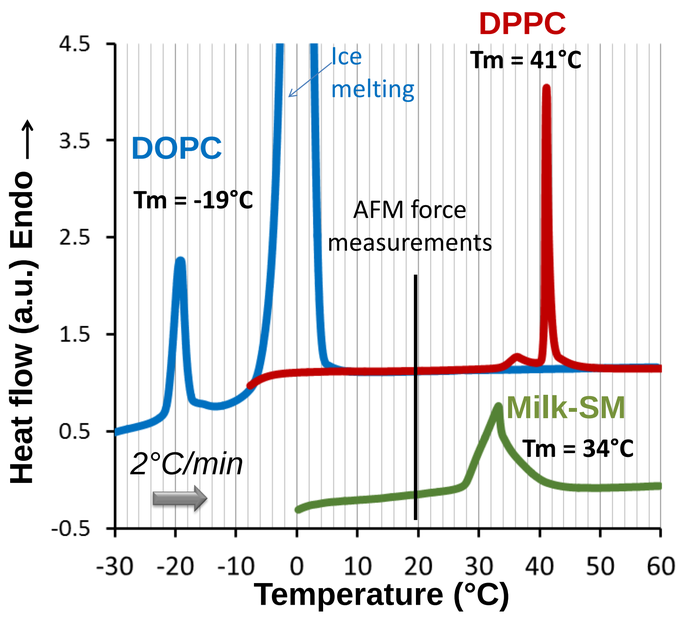
Fatty acid composition of polar lipids affects the elasticity of membranes

Chemical composition → **Physical state** → **Mechanical properties**

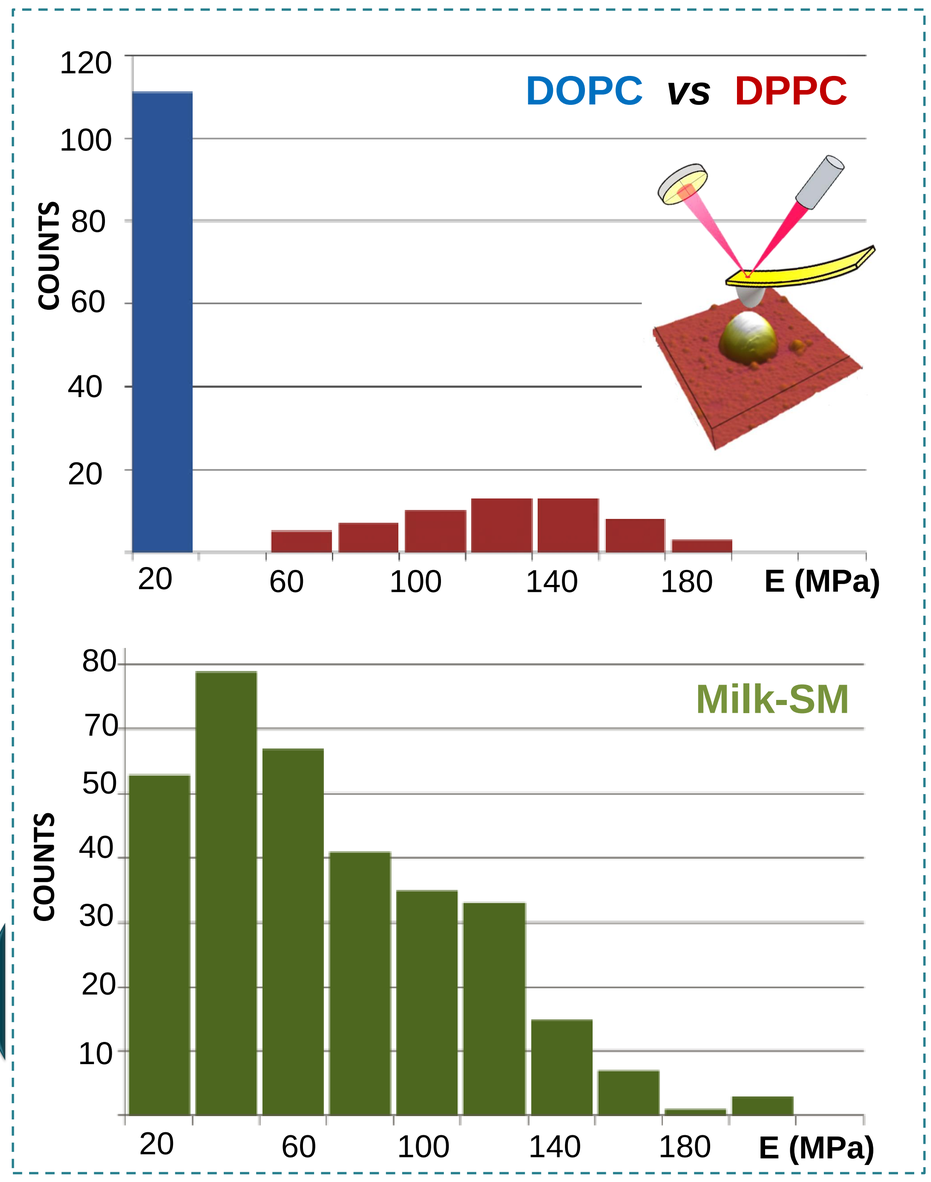


Unsaturated (DOPC) and saturated (DPPC) polar lipids versus molecular species of milk sphingomyelin (milk-SM).

DOPC: dioleoylphosphatidylcholine (18:1), DPPC: dipalmitoylphosphatidylcholine (16:0). Milk-SM contains long chain saturated fatty acids and 3% of unsaturated 24:1.



Differential scanning calorimetry thermograms of DOPC, DPPC and milk-SM multilamellar vesicles, showing the gel to fluid phase transition temperature (Tm).



Distribution of elasticity values for DOPC, DPPC and milk-SM vesicles, recorded at 20°C.

The elasticity of lipid membranes depends mainly on the physical state of lipids (gel vs. fluid) and consequently on their chemical composition (unsaturated vs. saturated). At 20°C, DOPC bilayers in the fluid state exhibited a lower elasticity (4 MPa) compared to DPPC bilayers in the gel state (130 MPa). Interestingly, milk-SM bilayers in the gel phase had dispersed values ranging from 20 to 200 MPa. This could be interpreted by the coexistence of several molecular species, i.e. the presence of saturated fatty acids with various chain lengths or the presence of unsaturated fatty acid 24:1 which may disturb the organization of the bilayer.

Outlooks:

These results open perspectives for liposome applications where the mechanical properties of the membrane are essential to ensure stability such as encapsulation in drug delivery or cosmetics. This study will also serve as reference for future investigations on membrane models of the MFGM to increase our knowledge of the role of heterogeneity in the stability of milk fat globule during processing or digestion.

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