On the structure of solid lipid nanoparticles for stabilizing oil-in-water emulsions

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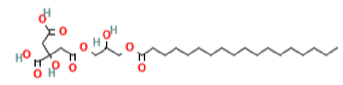
Background

- Solid lipid nanoparticles (SLNs) are colloidal systems composed of nanoscale lipid particles solid at room temperature
- Emulsions can be stabilized by solid particles adsorbing to the oil-water interface. This is known as a Pickering emulsion. Synthetic solid particles used for stabilization exhibit ideal uniformity in size and morphology. However, this often comes at the price of increased toxicity. Using natural particles allows for biocompatibility but achieving consistent and uniform size and morphology can be a challenge. In this research, SLNs are created and characterized in the interest of stabilizing oil-in-water (O/W) emulsions.
- Experimental techniques can be used to analyze particle and emulsion size and morphology while molecular dynamics simulation is necessary to understand the internal structure of the SLNs and how they adsorb to an oil-water interface

Materials and methods

Stearic acid (SA) CITREM

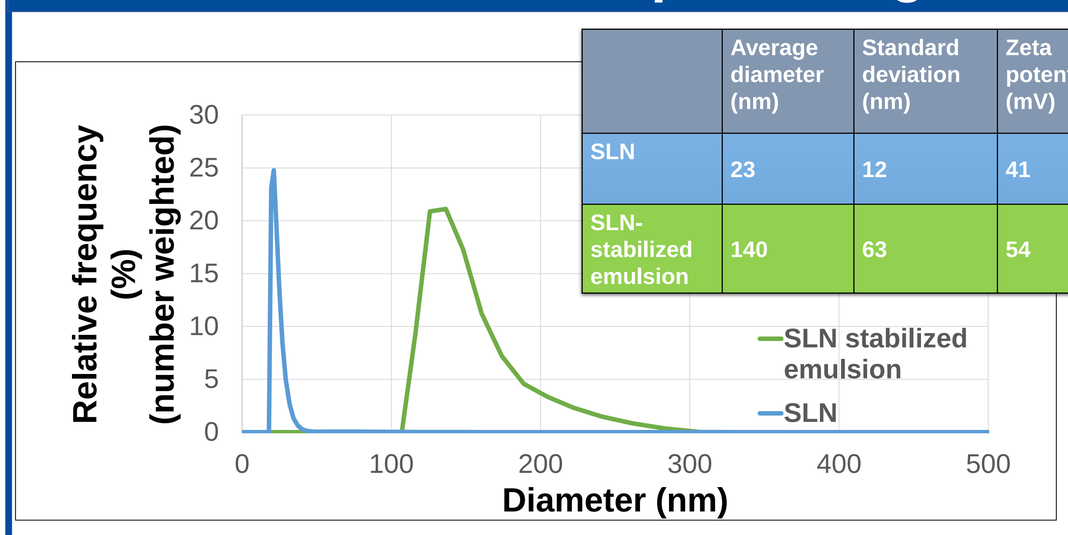


SA CITREM is a food-grade emulsifier consisting of citric acid esters of monoglycerides. It is amphiphilic with an HLB of ~12. SA CITREM also has a negative charge due to the citric acid head group. This negative charge is useful for preventing particle coalescence. Here, SA CITREM is used to make solid lipid nanoparticles (SLNs.)

SLN and SLN-stabilized emulsion preparation

To make the SLNs, SA CITREM and water are heated to 80°C before undergoing premixing and ultrasonic homogenization. The SLNs are then cooled to 4°C. The suspension is then premixed with 80 w/w% aqueous phase and 20 w/w% oil. The mixture undergoes high pressure homogenization at 4°C.

Particle and droplet sizing



	Average diameter (nm)	Standard deviation (nm)	Zeta potential (mV)
SLN	23	12	41
SLN-stabilized emulsion	140	63	54

Fig.1. Solid lipid nanoparticle (SLN) and SLN stabilized emulsion size distribution.

- SLNs stabilized oil droplets approximately 10x their size, as expected with Pickering emulsions
- Both displayed relatively narrow distributions
- Zeta potential was more negative when SLNs absorbed to droplets.

Scanning electron microscopy (SEM)

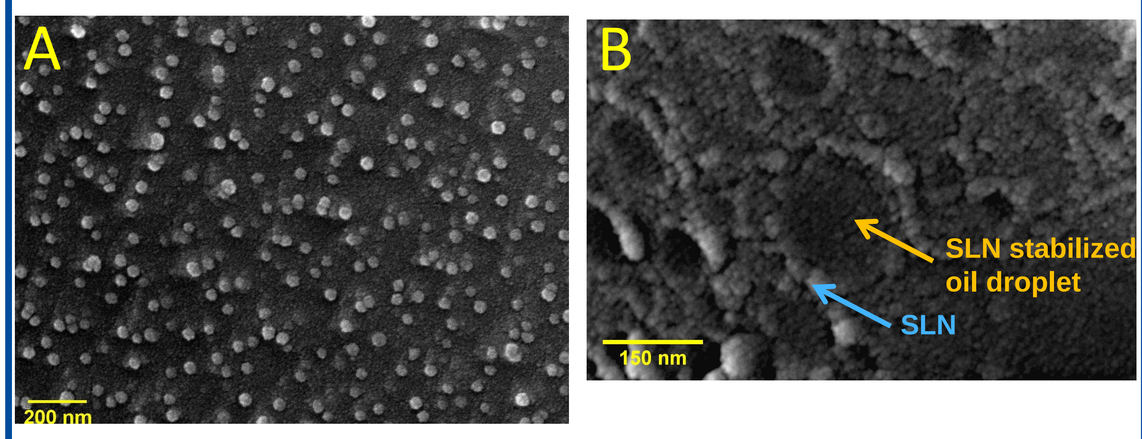
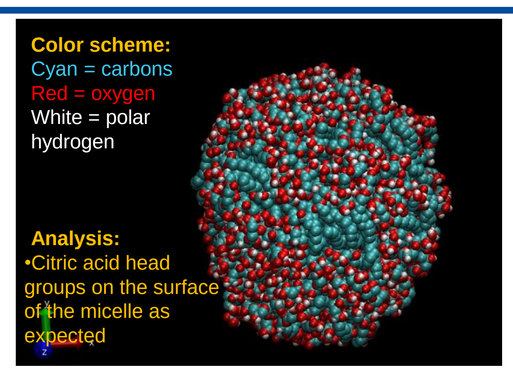


Fig.2. A: SLN suspension. SLNs appear spherical and uniform is size and shape. Diameter of SLNs are <50nm. **B:** SLN stabilized OW emulsion. Oil droplets can be seen as dark "craters" surrounded by SLNS.

- SLNs appear spherical and uniform
- SLNs <50nm stabilized emulsion drops 100-150nm in size

Molecular dynamics simulation

The molecular dynamics simulation program GROMACS was used to construct an SA CITREM nanoparticle and observe interactions at an oil droplet surface. The particle was created by placing 200 SA CITREM molecules in a water box. The temperature was held at 400 K and gradually cooled to 300 K to mimic laboratory conditions. The resulting structure was analyzed using a radial distribution function to determine the distribution of polar head groups and lipid chains around the center of the particle. Lastly, the particle was introduced to an oil surface to observe structure variation as a molten SLN was adsorbed.



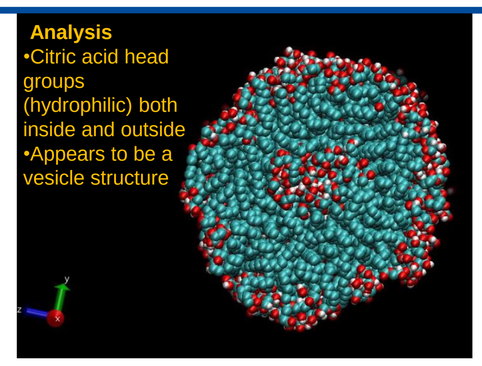


Fig.3. 200 SA CITREM in water resulting particle structure. **Left:** particle surface. **Right:** cross section to view inside particle.

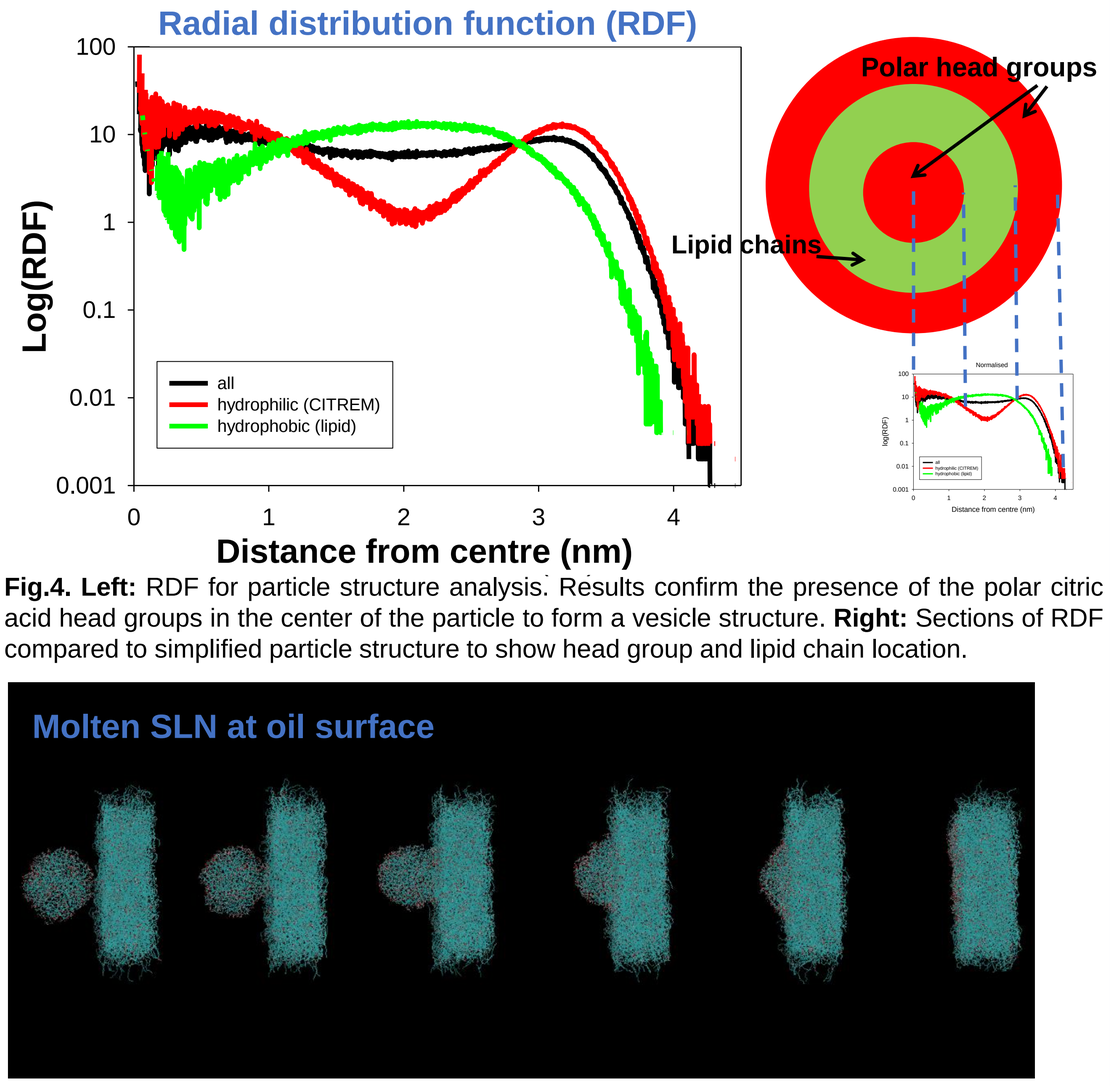


Fig.4. Left: RDF for particle structure analysis. Results confirm the presence of the polar citric acid head groups in the center of the particle to form a vesicle structure. **Right:** Sections of RDF compared to simplified particle structure to show head group and lipid chain location.

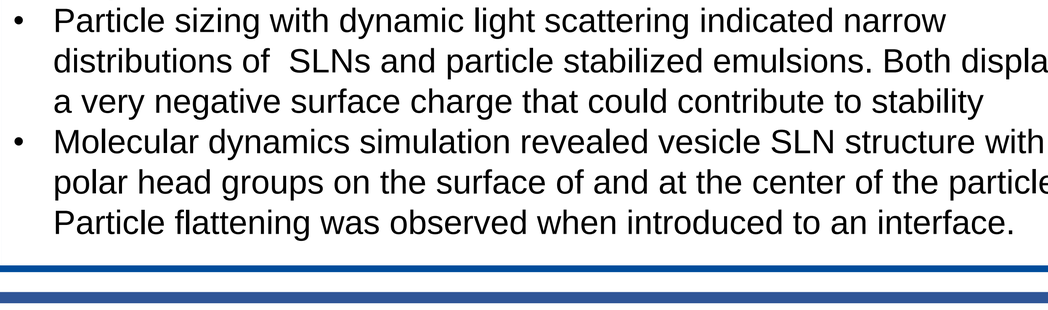


Fig.5. SA CITREM SLN introduced to oil droplet surface. Particle unfolding can be observed. Resulting structure appears to be a monolayer.

- MD simulation results indicate molten SLN flattening may occur when used to stabilize O/W emulsions.

Conclusions

- Scanning electron microscopy revealed SLNs of uniform size and shape. The stabilization of O/W emulsions was also confirmed
- Particle sizing with dynamic light scattering indicated narrow distributions of SLNs and particle stabilized emulsions. Both displayed a very negative surface charge that could contribute to stability
- Molecular dynamics simulation revealed vesicle SLN structure with polar head groups on the surface of and at the center of the particle. Particle flattening was observed when introduced to an interface.