

## Nanotechnology and Structure of Edible Fats

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The functional properties of fats and fat-structured foods, such as butter and chocolate, are a function of the structure and rheological properties of their underlying fat crystal networks. This fat crystal network arises upon crystallization of triacylglycerol molecules present in the fat into nanocrystals which rapidly aggregate into progressively larger mesostructures until a network is formed. Work in our laboratory has established quantitative relationships between the different levels of structure present in fats, from chemical composition, crystallization kinetics, solid state structure and microstructure to mechanical properties. A fractal scaling model was developed to explain these relationships,

$$\sigma_y = \frac{6\delta}{a} \Phi^{\frac{1}{3-D}} \quad \text{or} \quad G = \frac{A}{6\pi\gamma a d_o^2} \Phi^{\frac{1}{3-D}},$$

where  $\sigma_y$  is the yield stress,  $\delta$  is the crystal-melt interfacial tension,  $a$  is the primary particle size,  $\Phi$  is the solids' volume fraction,  $A$  is Hamaker's constant,  $\gamma$  is the strain at the limit of linearity,  $d_o$  is the interparticle separation distance, and  $D$  is the mass fractal dimension. This model has helped explain why fats with similar solid fat contents can have very different mechanical responses, and has changed our view of a fat from an orthodox crystalline solid to a colloidal gel. More recent work has focused on the characterization of the nanoscale of these plastic soft solids. Cryo-TEM and small-angle X-ray scattering techniques have revealed the "primary" crystals present in these materials in fact are an agglomerate of platelet-shaped single crystals of ~100x200x40 nm dimensions. These clusters, in turn, grow by cluster-cluster aggregation into larger fractal aggregates until a space-filling network is formed. We have also characterized inter-crystalline interaction forces using a Lifshitz approach and have been able to determine the contribution from London dispersion forces and Debye-Keesom forces to the total van der Waals' interaction. Our measurements suggest that van der Waals' forces are sufficient to explain the mechanical strength of a fat, and that, very surprisingly, permanent dipole-permanent dipole interaction are more important than transient induced dipole interaction forces in these systems.

Using synchrotron X-ray diffraction, our group was the first to report that fats can be oriented crystallographically by laminar shear, basically a nanotemplating process. The nanotemplated fat demonstrates increased mechanical strength and is more impermeable to oil. Moreover, we have also demonstrated the universality in the acceleration of polymorphic transformations in fats in a shear field. Our efforts also include the development of kinetic models to mechanistically describe phase transformation kinetics from solid state structure data, as well building a nanotemplating machine.

You will never look at chocolate in the same way after this talk.