Nanoscale Engineering of the Structure and Functionality of Edible Fats

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Fats and oils are extremely useful natural products which are widely used in foods, cosmetics and industrial applications. As the concern for the environment and health grows, consumers are demanding more natural, green and sustainable materials in everyday consumer products. Fats and oils are complex multicomponent mixtures of triacylglycerol molecular species. The nature of these molecular species are a function of both fatty acid composition and distribution within the TAG molecule. The purpose of this talk is to discuss the structure of fats and oils, from constituent TAG molecules to the crystals they form. Upon crystallization, TAG molecules form lamellae (shown in blue), which stack to form a highly asymmetric nanoplatelet with about ~8 TAG lamella (Figure 1)[1]. We have been able to engineer the thickness of these nanoplatelets by using specific surfactants and affecting the surface energy and surface nucleation behavior of TAGs on these crystalline nanoplatelets[2]. These nanoplatelets rapidly aggregate into colloidal structures of differing morphologies and size depending on external fields and concentration, forming networks which are responsible for the binding of oil, water vapour barrier properties, and mechanical properties of the fat. Our work has focused on developing an understanding of the functionality of fats from a structural perspective. Early work focused on the quantification of structure using small deformation rheological techniques. More recent work has focused on the use of scattering methods, in particular Ultra-Small Angle X-ray Scattering at synchrotron facilities to quantify atomic scale structure to mesoscale structure simulataneously, in a non-destructive fashion[3] (Figure 2) USAXS was particularly useful in helping us understand the nature of plasticity (plastic flow rheological behavior) in fats used for the manufacture of laminated bakery products, such as croissants. An greater number of discrete length scales and small nano and mesostructural features were associated with a greater plasticity. The opposite was observed for brittle materials. The engineering of the structure and functionality of fats is at hand.

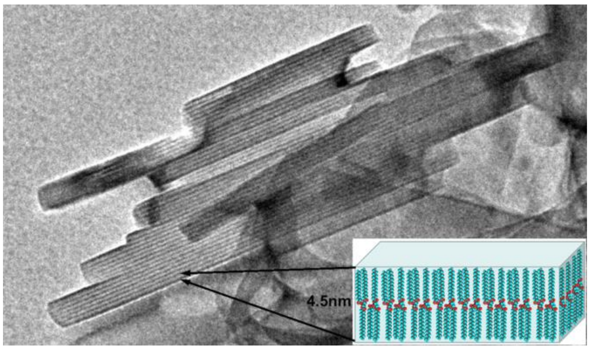

Figure 1. Cross-sectional view of a TAG nanoplatelet showing epitaxial molecular packing in the [001] direction

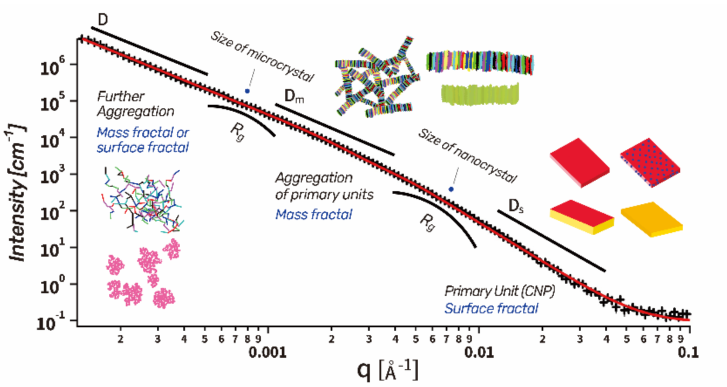

Figure 2. Characteristic USAXS pattern of an edible fat showing the different discrete length scales and the information that can be derived from such pattern. The cartoons represent the structures predicted from computer simulations of the scattering patterns.

References

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[2] Ramel, P., Co, E.D., Acevedo, N.A. and Marangoni, A.G. 2016. Nanoscale structure and functionality of fats. Progress in Lipid Research 64: 231–242
[3] Pink, D.A., Quinn, B., Peyronel, F. and Marangoni, A.G. 2013. Edible Oil Structures at Low and Intermediate Concentrations: I. Modelling, Computer Simulation and Predictions for X-ray Scattering. J. Applied Physics 114: 234901.