Engineering Principles of Rotating Membrane Emulsification

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The process of rotating membrane emulsification (RME) continues to interest researchers as a low energy technique to formulate emulsions[1]. By pressurising the phase to be dispersed through the pores of a membrane, individual droplets are grown at the membrane surface. Inducing shear through rotational motion of the membrane causes droplets to detach as they are introduced to the continuous phase (Fig. 1). This differs from conventional techniques in which the two phases are introduced prior to emulsification with the dispersed phase broken down into droplets by significant energy input[2]. Manipulation of parameters such as the applied pressure and shear rate gives a sensitive level of control over the emulsion structure.

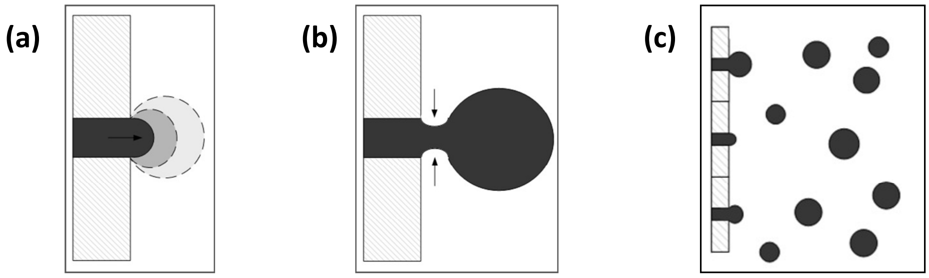

Fig 1: A schematic representing droplet growth (a), droplet detachment (b) and emulsion production (c).

We show that with consideration of how RME is operated, the process can be competitive with a rotor-stator mixer setup both in terms of rate of emulsion production and final droplet size attainable even with vastly lower applied shear (Fig. 2). The key to this is ensuring rapid adsorption of surfactant at the droplet interface as it forms at the membrane surface. This allows for droplets to detach quickly since the interfacial tension holding droplets at the surface reduces much faster. As a consequence, droplets detach at a much smaller size and with less likelihood of coalescence occurring between adjacent forming droplets.

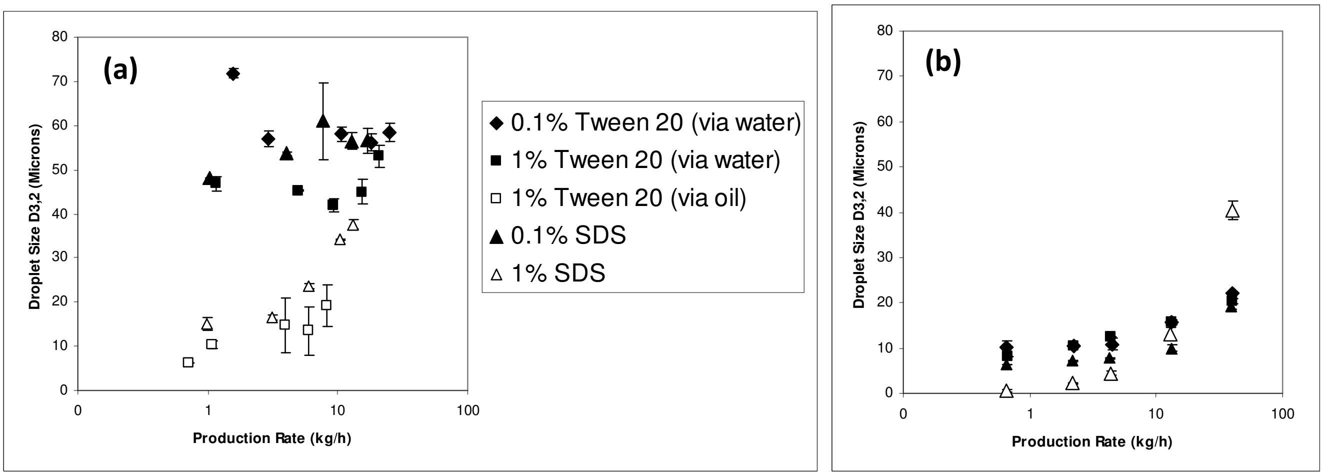

Fig 2: Droplet size data for different surfactant systems using RME (a) and Silverson rotor-stator mixer (b). The production rate considers formulation of ≈ 110g of 10% v/v sunflower oil in water emulsion and is modified by applied pressure and mixing time respectively.

A unique approach to ensure this is through the loading of surfactant into the dispersed phase - especially if this surfactant favours positioning itself within the other phase. This is demonstrated using Tween 20 within a dispersed phase of commercially available sunflower oil. When compared to the same quantity of surfactant delivered via the aqueous continuous phase, droplets between 3-8 times smaller could be produced (Fig. 3). This suggests a more economical use of surfactant alongside the other benefits of using RME for emulsion production.

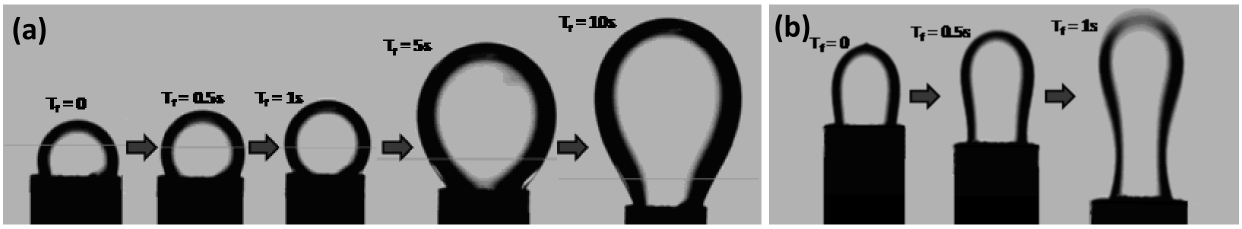

Fig 3: Images from Goniometer showing differences in the point of droplet detachment stage when 1% wt. Tween 20 is positioned within the continuous phase (a) and the dispersed phase (b). The droplet is inflated at a rate of 135 µl/min.

The purpose of this work is to understand the coupling mechanisms associated with the rate of droplet growth due to the dispersed phase flux and rate of detachment due to applied shear and surfactant adsorption kinetics. This is considered within the context of bringing RME towards an industrial scale.

Acknowledgement

The authors would like to thank Phil Taylor and Nina Viner at Syngenta and Patrick Mulqueen, as well as Charles Clifford, Martin Munz and Helen Sharman at the National Physical Laboratory for support. The project is co-funded by the Technology Strategy Board and the Engineering and Physical Sciences Research Council.

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