Spray-assisted formation of micrometer-sized emulsions

Supplementary information

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Supplementary Video 1: Time-lapse (10x sped up) of the emulsification of an aqueous solution containing 0.5 wt% of Tween 80 into dodecane containing 0.5 wt% of Span 80.

Emulsification mechanism

To study the influence of the kinetic energy of the aerosol drops on the emulsification process, we separate the atomizer from the oil bath by a 14 cm long glass tube, as shown in Figure S1.

Figure S1: Photograph showing the emulsification achieved by separating the atomization unit from the oil bath with a 14 cm long glass tube. The arrow indicates the formation of the emulsion drops in the oil bath.

The emulsification process is governed by the balance of interfacial tensions of the system. We use drop tensiometry to measure γ_{wa}, γ_{oa} and γ_{wo}, which denote the interfacial tensions between the water and the air, the oil and the air and the water and the oil, respectively. We use measured values to calculate the spreading coefficient $S = \gamma_{wa} - (\gamma_{oa} + \gamma_{wo})$. The results are summarized in Table S2.

Table S2: Interfacial tension and spreading coefficient of emulsion systems.

Dispersed phase	Continuous phase	γ_{wa} [mN m^{-1}]	γ_{oa} [mN m^{-1}]	γ_{wo} [mN m^{-1}]	S [mN m^{-1}]
Water	Dodecane	71	25	50	-4
Water 0.5 wt% Tween 80	Dodecane	44	25	7	12
Water 0.5 wt% Tween 80	Dodecane 0.5 wt% Span 80	44	24	< 1	19
Water	Dodecane 0.5 wt% Span 80	71	24	4	43
Water 0.5 wt% Tween 80	Mineral oil 0.5 wt% Span 80	44	29	2	13
Water 0.5 wt% Tween 80	HFE 7500 0.5 wt% Krytox	44	15	9	19

To test if the location of the surfactant is influencing the formation of emulsions we spray pure water into a bath of dodecane containing 0.5 wt% Span 80 and visualize the obtained drops with optical microscopy, as exemplified in Figure S3

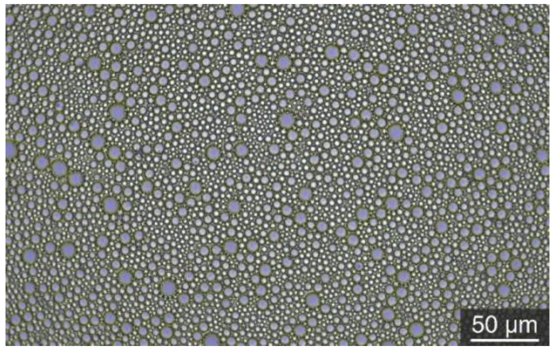

Figure S3: Micrograph showing an emulsion formed by spraying water into a dodecane solution containing 0.5 wt% Span 80.

Commercially available atomizer

Because the emulsification process is thermodynamically driven, it can easily be upscaled by using other types of atomizers. We illustrate the versatility of the emulsification process by employing a commercially available ultrasonic humidifier to produce emulsions composed of a dispersed aqueous phase containing 0.5 wt% Tween 80 in a continuous phase of dodecane containing 0.5 wt% Span 80. The obtained emulsion drops and their size distribution are exemplified in Figure S4.

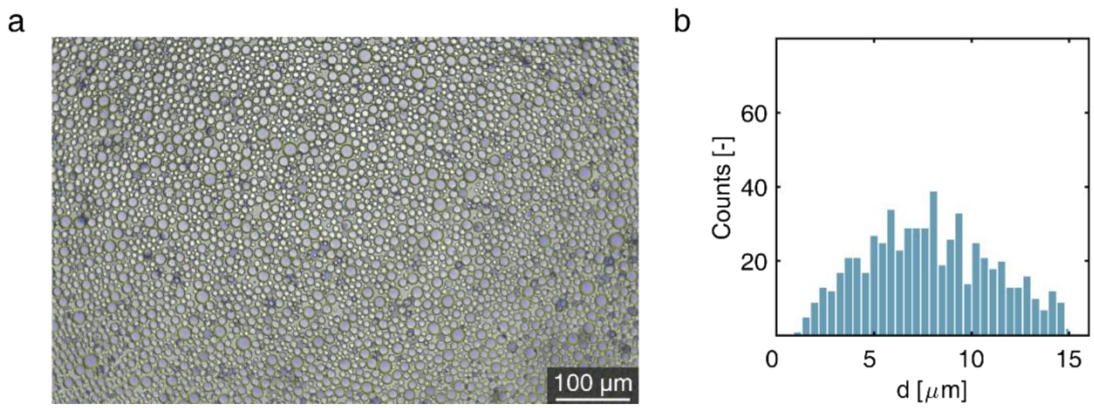

Figure S4: a) Micrograph and b) size distribution (N > 640 drops) of aqueous emulsion drops containing 0.5 wt% Tween 80 dispersed in dodecane containing 0.5 wt% of Span 80 produced with a commercial ultrasonic humidifier.