

Impact Of Electrolytes On Produced Water Destabilization: Plassard L.*†, Mouret A.†, Nieto-Draghi C.†, Dalmazzone C.†, Langevin D.‡, Argillier J-F.†

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Supporting Information

Figure S1 presents optical microscopy images of the PW creams obtained after one hour of centrifugation.

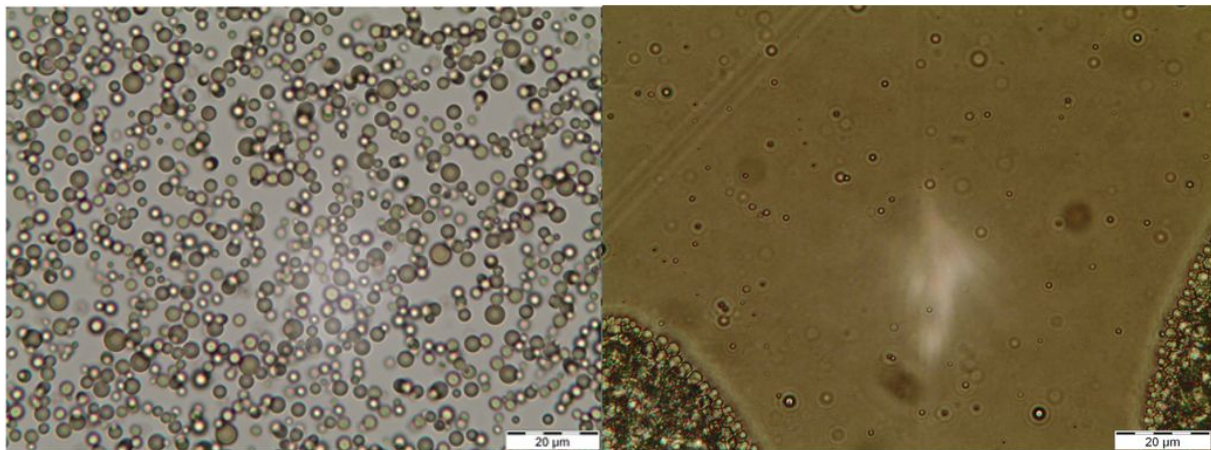


Figure S1: Optical microscope images of the creams that form after centrifugation of the production water containing 0.5 wt% diluted oil; stable emulsion (left; the emulsion was partially diluted) and onset of coalescence revealed by the appearance of a macroscopic oil film (right). Scale bar = 20 µm.

In the following, we will describe the calculation of the critical osmotic pressure.

Above a critical rotation speed in the centrifuge, oil droplets begin to coalesce and form a macroscopic oil layer. The critical speed depends on the characteristics of the centrifuge (volume and shape of the bowl, inclination, distance from the axis) and is not an intrinsic property of the emulsion. It is therefore preferable to give the results in terms of critical osmotic pressure.

The centrifugal force is balanced by the osmotic pressure gradient.

$$\frac{d\Pi(r)}{dr} = -\Delta\rho \times r \times \omega^2 \times \Phi(r) \quad (\text{S1})$$

In this equation, r corresponds to the distance between the measuring point and the rotation axis, $\Pi(r)$ to the osmotic pressure, $\Delta\rho$ to the density difference between oil and water phases, ω to the rotation speed and $\phi(r)$ to the volume fraction of droplets.

If $r \geq r_2$ (see Figure S2), there are no more oil droplets in the aqueous phase, then the osmotic pressure $\Pi(r_2)$ is equal to zero, as well as $\Phi(r_2)$. In the cream, $r_1 < r < r_2$, the pressure is large and ϕ is close to 1. Equation S1 can then be easily integrated, and we find the following relationship.

$$\Pi(r_1) - \Pi(r_2) = \Pi(r_1) = \Delta\rho \times \omega^2 \times \frac{(r_2^2 - r_1^2)}{2} \quad (\text{S2})$$

Here, r_1 and r_2 are the distances to the axis of the air-emulsion and emulsion-water interfaces respectively. Figure S2 shows the position of the liquid container in the centrifuge.

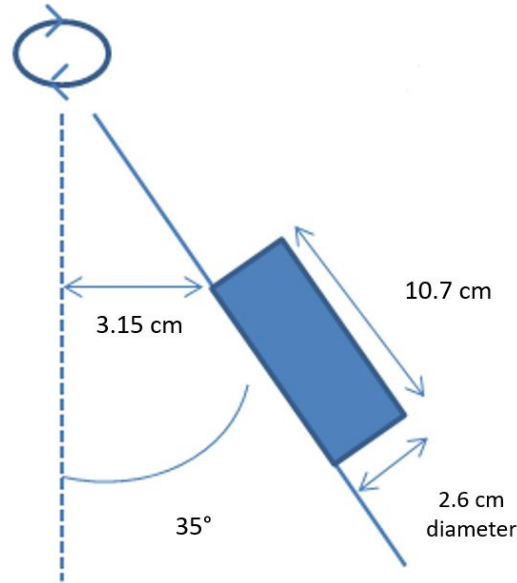


Figure S2: Representation of the position of the centrifuge tube in the centrifugal.

shows the creamed concentrated emulsion, represented by a thin red layer at the surface of the liquid (in blue). The emulsion layer is parallel to the axis of rotation. Since there are no more oil droplets in the blue region, the osmotic pressure is equal to zero for distances from the axis of rotation $r \geq r_2$. It is maximum for $r = r_1$. Figure S3 shows the position of the emulsion during centrifugation.

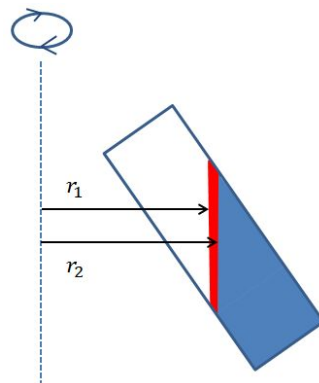


Figure S3: Representation of oil layer (in red) and the aqueous phase (in blue) during centrifugation.

As the volume of oil is very small, we find from equation S3.

$$\Pi(r_1) \sim \Delta\rho \times \omega^2 \times r_1 \times \Delta r \text{ with } \Delta r = r_2 - r_1 \quad (\text{S3})$$

The volume available in the tube is 56.8 cm³, which is more than the 40 cm³ of liquid that was used for each test. At rest, when the tube is upright, the height of the liquid L is 7.5 cm. In rotation, the oil rises on the side to a height of 9.4 cm. This is less than the height of the tube (10.7 cm), as represented in Figure S3. The distance r_1 from the axis of rotation is about 6.3 cm. The volume of cream is 0.22 cm³ for 40 cm³ of the sample. The centrifuged cream is a cylinder of height Δr and elliptical section of volume:

$$V = \frac{\Delta r \times \pi \times a^2}{\sin 35} \quad (\text{S4})$$

a being the tube radius. This gives a Δr of 1.96.10⁻⁴ m, i.e. about 0.20 mm.

In these centrifugation trials, osmotic equilibrium must be reached in order to determine the critical osmotic pressure. The oil droplet concentrated phase of the emulsions is observed with an optical microscope after centrifugation, i.e. one-hour waiting time. Sonnevile-Aubrun et al. waited about 10 hours with their emulsions⁴⁸. In our work, the cream layer is very thin ($\Delta r = 0.20$ mm), of the order of capillary length ($l_{cap} = 0.21$ mm for $g^* = 480g$, i.e. the lowest rotation of this work), so the oil droplet fraction should not change. The capillary length is calculated from the following relation:

$$l_{cap} = \sqrt{\frac{\gamma}{\Delta\rho \times g^*}} \quad (\text{S5})$$

In this equation, γ is the interfacial tension between the phases (in N/m), $\Delta\rho$ is the density difference between the phases (in kg/m³) and g^* is the applied gravity (m/s²).