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**Citation:** VLADISAVLJEVIC, G.T. ... et al., 2003. Direct observation of droplet formation in membrane emulsification. DDS Seminar - Development of Lipid Microcarriers and Their Application to Drug Delivery Systems, Sadowara, Japan, Abstracts, p.3.

**Additional Information:**

- This is an abstract.

**Metadata Record:** [https://dspace.lboro.ac.uk/2134/10678](https://dspace.lboro.ac.uk/2134/10678)

**Version:** Accepted for publication

Please cite the published version.
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Direct observation of droplet formation in membrane emulsification

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Membrane emulsification process was observed in real time through a transparent flat plate placed at the upper side of a specially designed membrane module. A microscope video system consisting of an inverted metallographic microscope (MS-511-M, Seiwa Optical Co., Ltd., Tokyo), a high-resolution color CCD camera (LCL-211H, Watec America Corp. USA) and a 20-inch monitor (PVM-20M4J, Sony Co., Tokyo) was used. The total monitor-based magnification was 2000. The process was recorded on a video recorder (HR-DVS3, JVC, Japan) using Mini DV video tapes. The MPEG video clips were generated from the recorded tapes using the Giga Pocket Ver. 2.0 software (Sony, Japan). The still images were captured using the V-shot photo grabber (Canopus, Japan). The droplet size was estimated from the captured still images using the WinRoof image analysis software (Mitani Co., Japan).

The experiments have been carried out using disk-type SPG or MPG membranes (the total diameter = 25 mm, the effective diameter = 16.4 mm, the effective area = 2.11 cm²) with a mean pore size of 10.2-16.3 µm. The dispersed phase flow rate was 0.1-5 ml/h corresponding to a dispersed phase flux of 0.47-23.7 l/(m²h). The membrane was mounted between two flat glass plates using spacers to form the upper and lower compartments between the membrane surface and glass plates. The continuous phase flowed through the upper compartment in once-through mode, while the lower compartment was filled with the dispersed phase. The dispersed phase (pure soybean oil or W/O emulsion) was pressed through the membrane at a constant flow rate using a syringe pump (Pump 11, HARVARD, Holliston, USA) with a 10-ml syringe. The thickness of continuous phase film above the membrane surface was 3.6 mm.

At the dispersed phase flux of 0.5 l/(m²h) the percentage of active pores was about 0.4 % and the mean frequency of droplet formation from the active pores was 0.14 s⁻¹, i.e., the mean time interval between two successive droplets formed at the same pore was about 7 s. The frequency of droplet formation at the same pore was very stable, but varied over a wide range at different active pores. The frequency of droplet formation increased with increasing the dispersed phase flux. The typical images captured from the recorded tapes are shown in Fig. 1.

(a) J_d = 0.5 l/(m²h)  (b) J_d = 1.4 l/(m²h)

Fig. 1. Two images captured from the recorded video clips at different dispersed phase fluxes (preparation of O/W emulsion using 1 wt. % Tween 80 as emulsifier and a 15 µm-SPG membrane).