Production of oil-in-water (O/W) emulsions of unrefined pumpkin seed oil with controlled particle size distribution using membrane emulsification

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Emulsions are multiphase dispersed systems consisting of two (or more) immiscible liquids, e.g. water and oil. Depending on which is the dispersed phase and which is the continuous phase, there are two types of single emulsions: oil-in-water (O/W) and water-in-oil (W/O) emulsions. In this work, O/W emulsions have been prepared by injecting unrefined pumpkin seed oil through a nickel plate membrane into an aqueous surfactant solution (Tween® 20 or Pluronic® F-68 with a concentration of 2 mas/vol %). The pumpkin seed oil with a density of 913.4 kg m^{-3} and a viscosity of 55.01 mPa s at 298 K was kindly donated by Tovarna Olja GEA (Slovenska Bistrica, Slovenia) and was injected through the membrane at a constant rate using a peristaltic pump. Pumpkin seed oil has a high nutritional value due to its high content of sterols and vitamin E.

The shear stress required for droplet detachment from the membrane surface was provided by agitation of the continuous phase using a two-blade paddle stirrer, as it is seen in Fig. 1 (a). Two membranes with regular pore arrangment have been used, a ring membrane containing open pores only in the region of maximum wall shear stress (the annular region B in Fig. 1 (b)) and the whole membrane containing open pores over the whole cross section of the membrane plate.

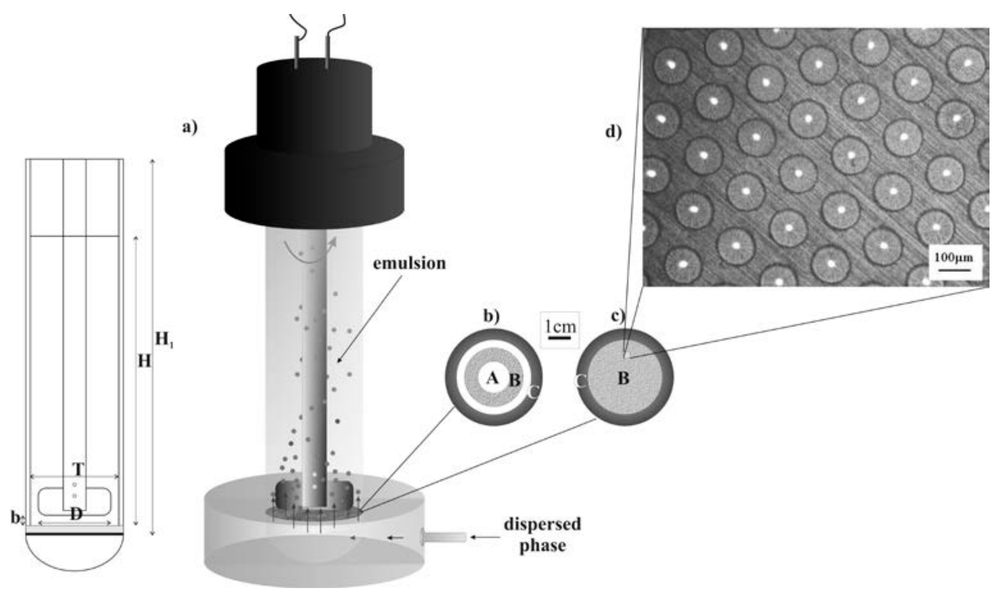

Figure 1. a) Schematic diagram showing a Micropore dispersion cell. b) Schematic view of the ring membrane. c) Schematic view of the whole membrane (region A indicates pores closed off, region B indicates open pores, and region C indicates the position where the gasket surrounding the membrane inside the stirred cell sits). d) Micrograph of a portion of membrane surface.

The emulsion particle size distribution has strongly depended on the operating conditions and the physicochemical properties of the oil and aqueous phase. In this work, the effect of the paddle stirrer rotation speed, the transmembrane flux, the mean pore size and the membrane type (ring or whole) on the particle size distribution have been investigated. As can be seen in Fig. 2 (a), the median droplet diameter sharply decreases as the paddle stirrer rotational speed increases from 200 to 600 rpm and tends to a constant limiting value with a further increase in the rotational speed. It was probably due to the fact that the boundary layer thickness was virtually constant at the high rotational speeds. A smallest relative span factor of 0.383 corresponding to the narrowest particle size distribution has been obtained at the agitation speed of 596 rpm and the mean droplet diameter of 113 μm.

The effect of the variation of the oil injection rate on the mean particle size and the relative span factor at the constant rotational speed of 596 rpm was shown in Fig. 2 (b). The mean particle size increases with an increase in the oil injection rate. The most uniform oil droplets have been obtained at the minimum oil injection rate of 320 $lm^{-2}h^{-1}$. Almost no difference in the particle size distribution has been found for the whole and ring membrane. As shown in Fig. 2 (b), the mean particle size of the Pluronic F68-stabilised droplets was greater that that for Tween 20-stabilised droplets, which is a consequence of the greater interfacial tension in the presence of Pluronic F68. The interfacial tension force is the main force preventing the droplet detachment and therefore the larger particles are formed at the greater interfacial tension.

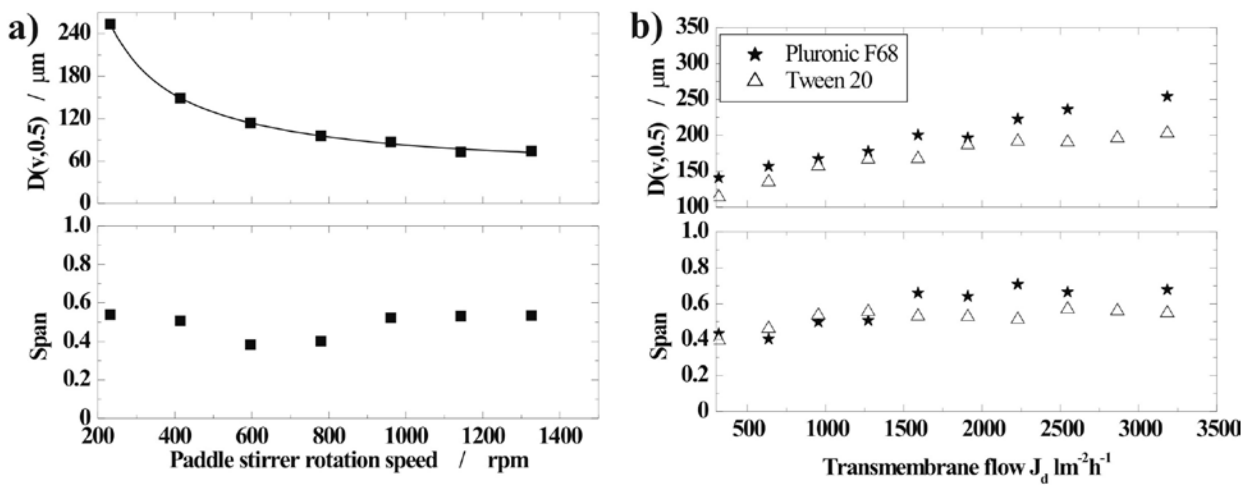

Figure 2. a) Effect of the stirrer rotational speed on the median droplet diameter and the span of the particle size distribution (whole 20-μm membrane, continuous phase: 2% Tween 20, J_d=320 $lm^{-2}h^{-1}$. b) Effect of the transmembrane flux on the mean particle diameter and the span of the particle size distribution (ring 20-μm membrane at 596 rpm).

The experimental results show that relatively uniform droplets of unrefined pumpkin seed oil can be prepared by injection of oil phase through the nickel membrane into a stirred aqueous surfactant solution. The mean particle size and particle size distribution can be controlled by the variation of the stirrer speed and the oil injection rate. The uniform droplets of pumpkin seed oil can be used as microcarriers for encapsulation of lipophilic active ingredients in various food, cosmetic, and pharmaceutical formulations.