SUPPLEMENTARY INFORMATION

for

Microscale solute flow probed with rotating microbead trapped in optical vortex

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Details on viscosity calculations and the influence of evaporation

Let us consider a circular chamber filled with 78 µl of water. The average mass of a single sucrose crystal was estimated at (1.0±0.1) mg. Before the addition of the first sucrose crystal the concentration is 0% (pure water). By adding subsequent sucrose crystals the concentration (w/w) should be equal to: (1.27±0.12)% for 1 crystal, (2.50±0.24)% for 2 crystals and (3.70±0.35)% for 3 crystals. These concentrations refer to the solutions of fully dissolved sucrose. Viscosity of aqueous sucrose solutions at different concentrations at 25°C can be found in literature (Swindells 1958). In order to obtain the viscosity values for particular concentrations, the literature data points were fitted with a biexponential function (Fig. SI.1) of a form

$$f(x) = a\exp(bx) + c\exp(dx) \tag{SI.1}$$

The fitted coefficients are: a = 0.001788; b = 0.1651; c = 0.7892; d = 0.03901. Given the equation, one can calculate the viscosity of 1, 2 and 3-crystal solution. For this paper it is more convenient to use relative viscosity, i.e. viscosity of a given solution divided by the viscosity of water.

Table SI.1 Literature data for the viscosity of sucrose solutions at different concentrations (w/w) at 25°C. Source: Swindells (1958) except for *Venard (1975).

sucrose concentration [%, w/w]	viscosity [mPa·s]
*0	0.89
20	1.695
30	2.735
40	5.164
50	12.40
60	43.03

The water evaporates during the experiment which may have noticeable impact on the measurements in case of long-lasting experiments, such as one-bead experiment in circular chamber (almost 23-minute long). As mentioned in the manuscript (Section 5.1) evaporation starts at the gap in the chamber (Fig. SI.2a) and progresses in a vertical direction until a substrate becomes dry. Further evaporation gives rise to the concave meniscus which propagates horizontally in the fluid layer (Fig. SI.2b). The meniscus can be observed with the naked eye (Fig. SI.2c). It takes about 20 minutes until the meniscus starts to form. It means that the volume of water in the open area evaporates in 20 minutes. For a 1.5 mm wide gap the volume of the open region is about 9.4% of the total chamber volume. Thus, the evaporated volume is about 7.3 µl. Assuming that evaporation rate is constant in time, one can calculate the water loss at any moment of the experiment. Let us consider the first sucrose addition. In Fig. 5a first crystal was added in the 188. second of the experiment. The viscosity undergoes a sudden jump and then starts to lower and stabilize. Just before the addition of the second crystal (492. second) the viscosity should be closest to the literature value (blue strips in Fig. 5b) since the dissolution has almost or completely finished. However, until then about 2.9 µl of water have already evaporated. One needs to recalculate literature values for the slightly increased concentration (dashed red line in Fig. 5b). The more sucrose added and the longer the experiment, the larger discrepancy between "with" and "without evaporation" case. It is worth mentioning that the described evaporation rate holds for halogen lamp illumination producing significant amounts of heat ("hot" light source). Further in the manuscript halogen lamp was replaced with a LED source ("cold" light source). Then, the evaporation slows down more than twice – the meniscus starts to arise after about 45 minutes.

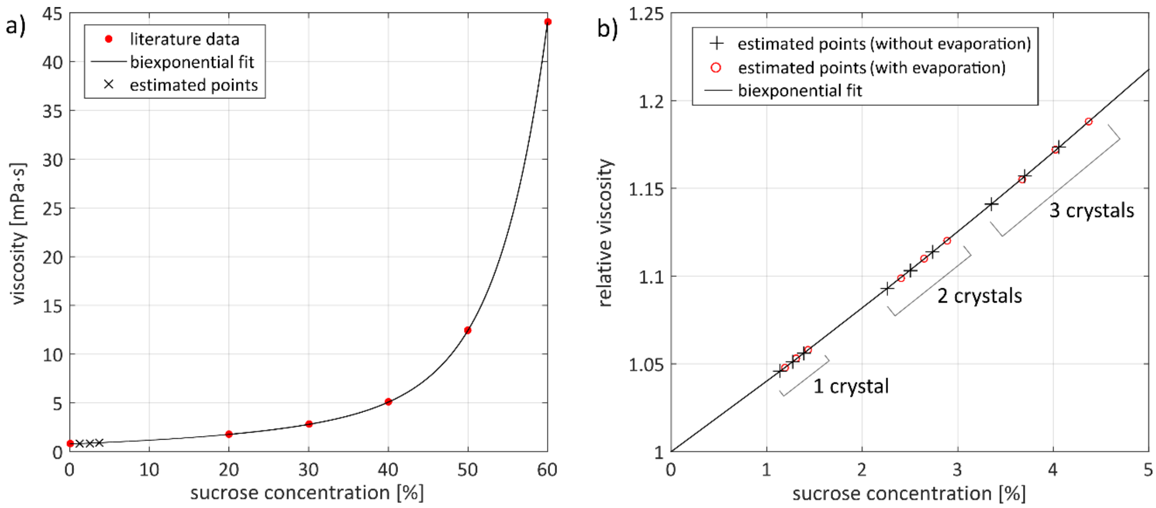

Fig. SI.1 Biexponential function (solid black line) $f(x) = 0.001788\exp(0.1651x) + 0.7892\exp(0.03901x)$ fitted to the literature data (from Table SI.1; red dots); (a) The evaluated sucrose concentrations for average mass of 1-3 sucrose crystals dissolved in a circular chamber were marked with ‘x’ signs; (b) Relative viscosity for small sucrose concentrations based on the fit. The viscosity for estimated sucrose concentrations with neglected evaporation were marked with ‘+’ signs. There are three points for each crystal addition representing three distinctive cases: the lowest concentration (each crystal of 0.9 mg), the average concentration (each crystal of 1.0 mg) and the highest concentration (each crystal of 1.1 mg). Analogously, the viscosity for estimated sucrose concentrations with evaporation included were marked with red circles

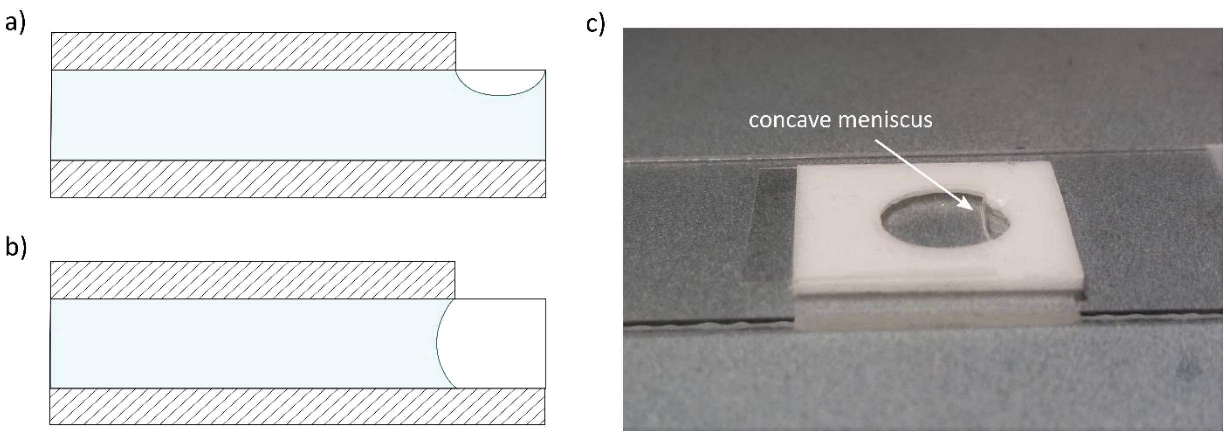

Fig. SI.2 Evaporation in the circular chamber; (a) evaporation starts at the gap region and continues downwards the chamber; (b) after the entire open area gets dry, the concave meniscus appears and propagates horizontally into the fluid layer; (c) the photo of a meniscus in the sample. Here, instead of two coverslips there is one coverslip (top) and one standard microscope slide (bottom)

References

Swindells JF, United States National Bureau of Standards (1958) Viscosities of Sucrose Solutions At Various Temperatures: Tables of Recalculated Values, Washington

Venard JK, Street RL (1975) Elementary Fluid Mechanics, 5th ed., Wiley, New York