Cross-flow ultrafiltration of skim milk assisted by ultrasound: multi-scale approach

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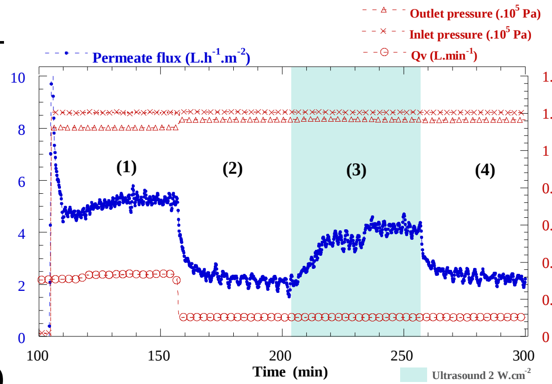
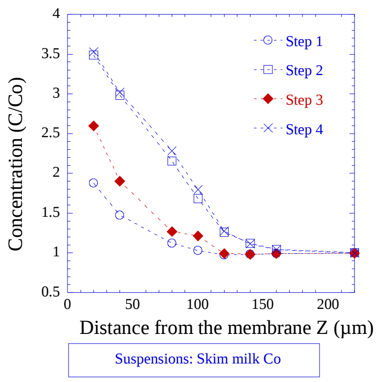
The bottleneck of skim milk ultrafiltration (UF) is the fouling phenomenon that affects the process performance thus limits the productivity. Several strategies have been chosen to control fouling. Some proposed to increase the shear rate close to the membrane [3], others suggested different procedures such as backpulsing[4], pulsating or reversed feed flows[5]. The ultrasonic-assisted filtration processes have been also proposed to enhance the cleaning process or the permeate flux. Several successful examples can already be found in literature [6-7].
Our recent work has shown a great interest to apply *in-situ* ultrasound (US) in colloidal suspensions filtration: with a designed 'Cross-Flow US-coupled Filtration Cell' at low US power (2 $W.cm^{-2}$), a significant increase of permeate flux was observed without damaging the membrane structure [8].
Using the designed 'SAXS Cross-Flow US-coupled Filtration Cell', this study is devoted to enhance skim milk ultrafiltration by applying *in-situ* ultrasonication and to characterize effects of ultrasound at multi-scales: the macroscopic results, presented by the permeate flux, have been combined with simultaneous detections at nanometer length scale, revealed by *in-situ* SAXS measurements of synchrotron radiation [9].

Skim milk suspensions were prepared from 'low heat' Bovine Skim Milk Powder at C_0=27 $g.L^{-1}$ in casein micelle content. Figure.1a displays the evolution of permeate flux J_v, inlet/outlet pressures of filtration cell and cross-flow rate Q_v over time. The filtration run is divided into 4 steps according to different operating conditions.



a)



b)

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Fig.1. Combination of macro-scale results and nano-scale detections during milk ultrafiltration (C = Co, pH 6.8). T = 25±1°C. Ultrasound: 20 kHz, 2 W.cm^{-2}. a) Cross-flow filtration curve, b) Related concentration profiles at steady state from the membrane surface to the bulk, deduced from *in-situ* SAXS measurements.

According to figure 1, a simultaneous ultrasonic irradiation has been shown as an efficient way to improve cross-flow ultrafiltration of skim milk with a factor of 2: It has led to a significant increase of permeate flux, which can be explained by a partial disruption of the concentrated layer, as evidenced from *in-situ* SAXS measurements These results emphasis the promising potential in applying in-situ ultrasonication to membrane separation processes in dairy industry.

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