Politecnico di Torino

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Principles of osmotic membrane distillation (OMD) and its application to concentrate heat and shear sensitive substances

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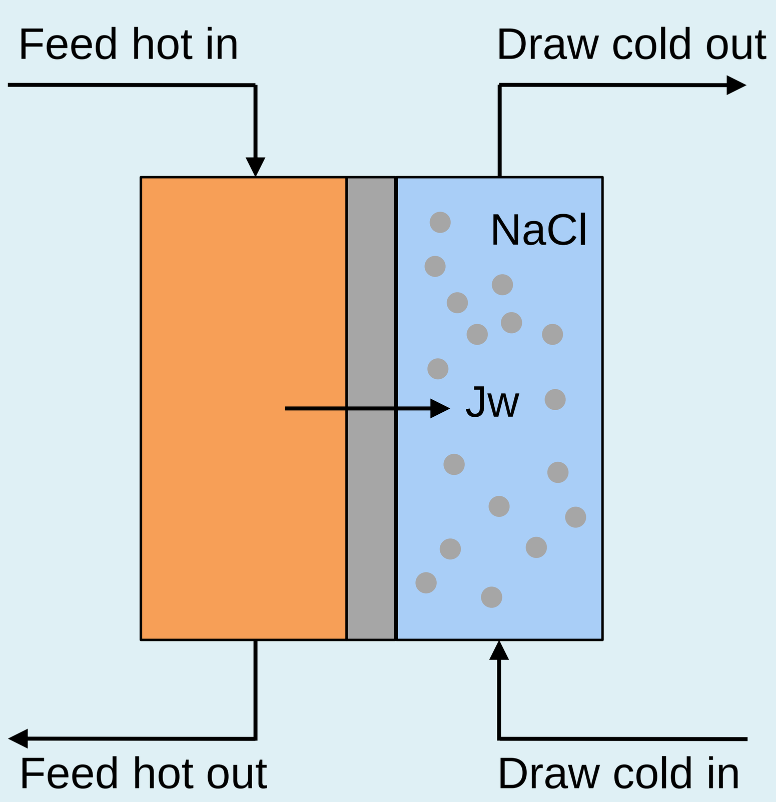
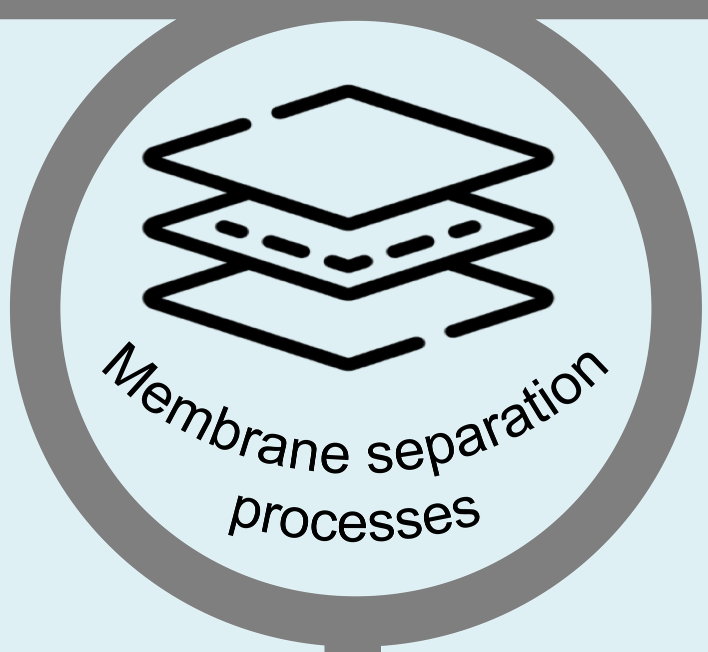


Introduction and objectives

The aim of the research is to understand and unravel how **membrane distillation (MD)** processes can be combined with **forward osmosis (FO).** The idea beyond the research is the combination of the driving forces due to both **temperature and salinity gradients**. In details, the performance of MD system may be increased utilizing an hyper-saline extraction solution (or draw solution as it is called in FO) in the distillate cold side of the system to exploit also a concentration gradient that enhance the water flux from the diluted side (hot water) to the draw side (cold water).

The utilized system is thus represent by a common direct contact MD unit where the streams are separated by an hydrophobic membrane. The feed water is heated up while the draw solution is cooled down. The most important take-home message is that **osmotic membrane distillation (OMD)** processes can be utilized solely when the final objective is the concentration of the feed water given that the production of clean water is infeasible because the common distillate side is replaced with an hyper-saline stream.

Membrane distillation (MD) + Osmotic distillation (OD) = Osmotic membrane distillation (OMD)

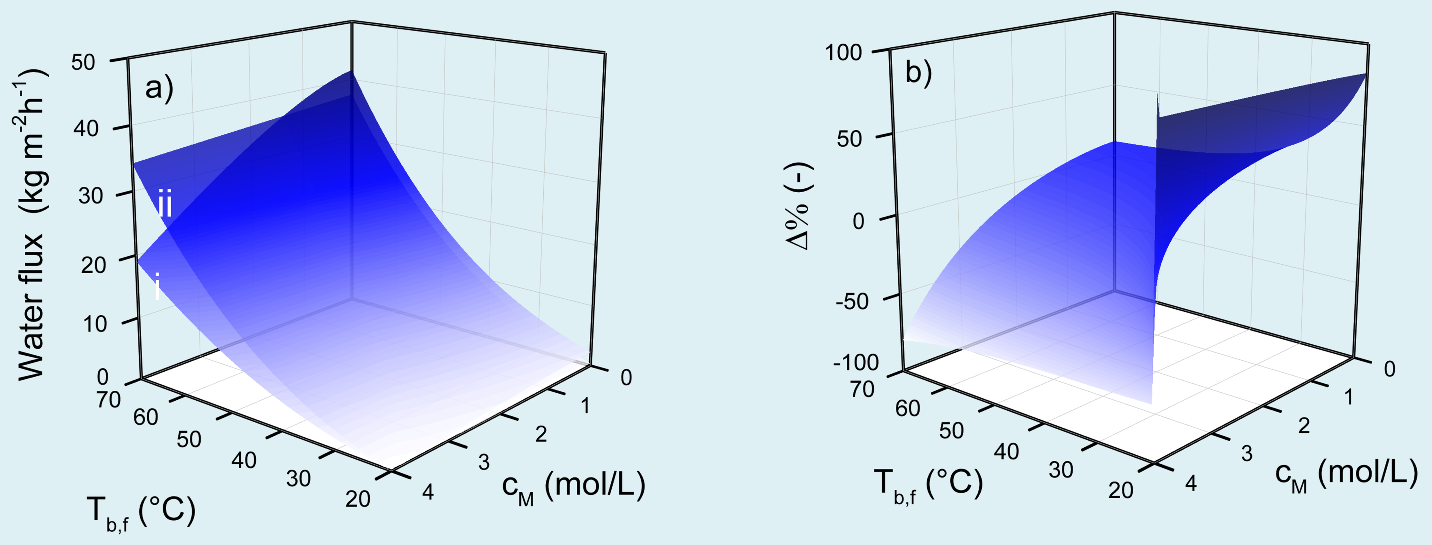


OMD principles

M. Morciano et al., 2022, "Osmotic membrane distillation for the extraction of valuable resources from water streams" – under review

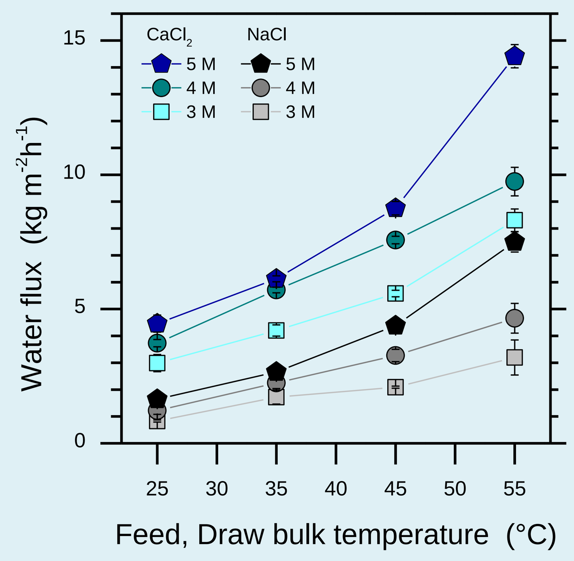
1) Theoretical analysis and modelling

Heat and mass transfer mechanisms occurring both across the membrane and in the feed and draw channels are incorporated in the developed model represented in (i) and derived from the combination of Maxwell–Stefan and dusty-gas models to evaluate the specific vapor mass flow rate passing through the membrane.



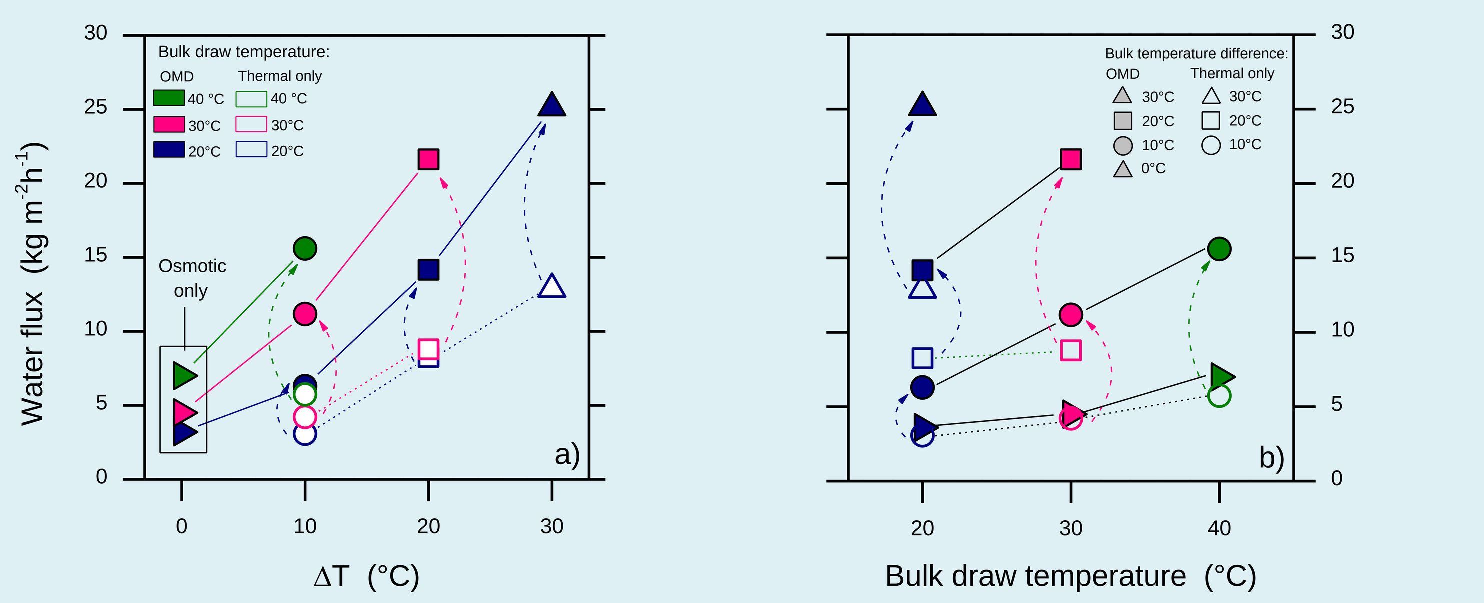
2) Preliminary osmotic distillation experiments

Data obtained by solely utilizing the driving force exerted by the salinity difference, while maintaining an equal bulk temperature on both the feed and draw sides, were performed to assess the impact of OD on performance. Sodium chloride and calcium chloride were both investigated as draw agents. As expected, the asymmetric solute leads to higher fluxes compared to former, due to a higher osmotic pressure and thus lower activity of the draw solution, at the same solution molarity.



3) Osmotic membrane distillation: driving force unravelled

As expected, the water flux was larger if a larger temperature difference was maintained between the two membrane sides. However, contrary to the pure MD case, this gain in productivity appeared to increase more than linearly for the OMD case as a function of bulk temperature difference.



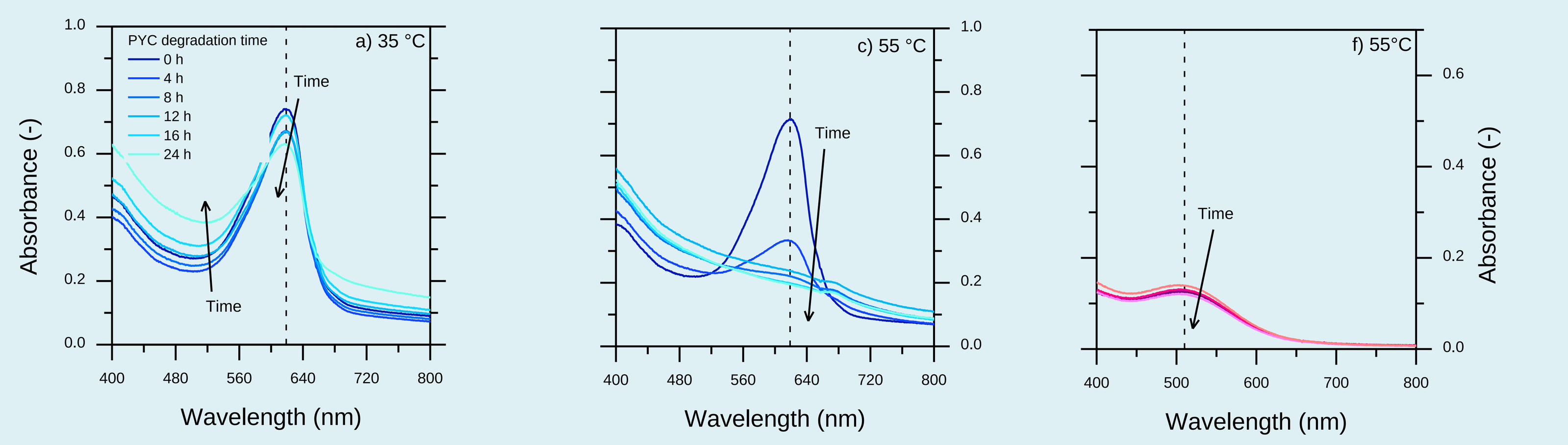
OMD applications

E. Bertozzi et al., 2022, "Concentration of phycocyanin and coffee extracts in aqueous solutions with osmotically-assisted membrane distillation" – under review

This follow-up research was conducted to assess the practical application of the previously investigated OMD process to concentrate valuable substances such as phycocyanin (PYC) and coffee extracts. In particular, phycocyanin is well known to be very sensitive to heat and shear-stresses and thus a low cross-flow velocity OMD system working at 45°C is considered suitable for PYC concentration.

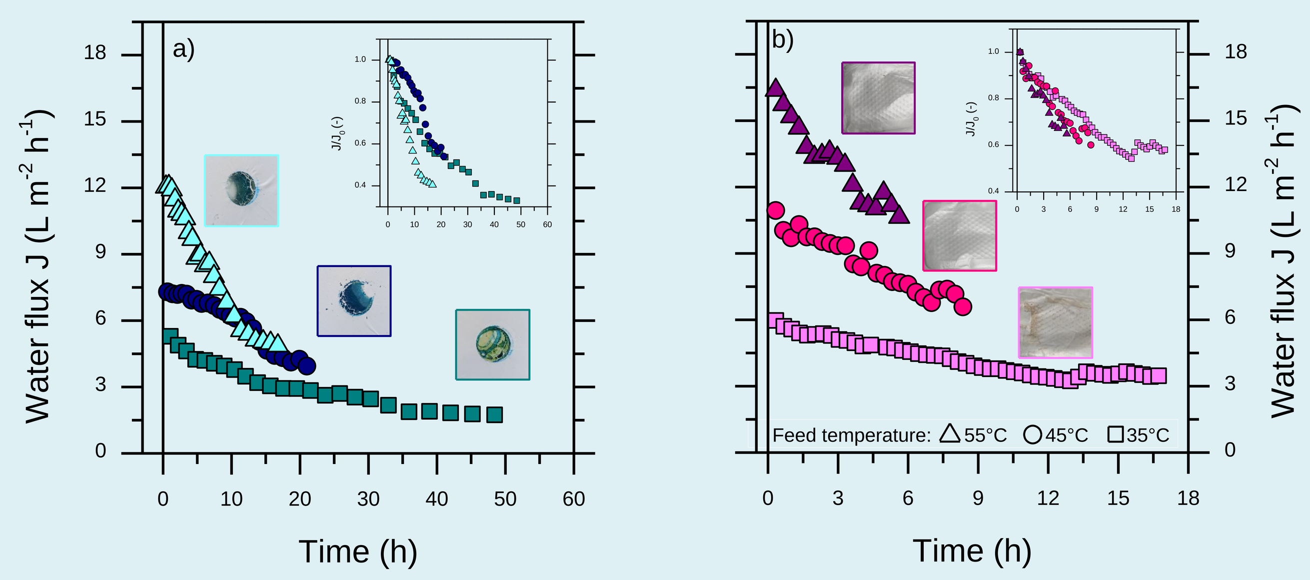
1) Batch degradation

Preliminary batch experiments at constant temperature of 35°C, 45°C and 55°C were performed to assess the expected PYC and total flavonoid content degradation during the OMD process.



2) OMD process concentration productivity

The aqueous PYC and coffee extract solutions were then concentrated in the OMD bench-scale system at the three temperatures keeping the cold draw solution at 25°C. Fouling is more detrimental at higher temperatures.



3) Quality of the concentrated substances

PYC and CAF concentrations and TOC were compared to the final expected concentration value based on the effective concentration factor. The optimal process temperature is 35°C for PYC while for SCGs extract medium-high temperatures (i.e., 45-55°C) are shown to be effective.