# Mem4SusDiary

## Membranes for efficient and sustainable downstream separations in dairy processing

Mem4SusDiary aims to demonstrate a novel NF process using ceramic membranes with tuned surface chemistry for efficient demineralization and pre-concentration of milk whey before ion exchange.

## THE CONTEXT

Milk whey is one of the main by-products of the dairy industry, having excellent nutritional properties. Current demineralization processes based on ion exchange (IEX) resins are becoming more and more uneconomical due to increasing resin regeneration costs. Partial demineralization of milk whey by nanofiltration (NF) prior to IEX would allow for a significant reduction of these regeneration costs (chemicals, water), while also enabling a flexible capacity enhancement.

Membrane filtration can be considered a "natural" technology choice for food processing thanks to its clean and energy-efficient character, gentle processing conditions, flexibility, scalability, and complementarity with electrification trends. Despite these features and the clear opportunities for $CO_2$-savings, implementation of membrane filtration is still relatively scarce and hampered by technical challenges such as lack of robust membranes in the market. However, previous successful research has shown that tailored ceramic membranes based on innovative modification/functionalization platforms and combining the robustness of ceramic membranes with the flexibility of polymeric membranes, can overcome these challenges.

The developed membrane process using modified ceramic membranes will allow FrieslandCampina to make their core production processes significantly more sustainable and cost-effective. Moreover, the selected show case studied in this project has a wide replication potential and will therefore contribute to accelerating the implementation of membrane filtration in dairy processing and the food industry in general.



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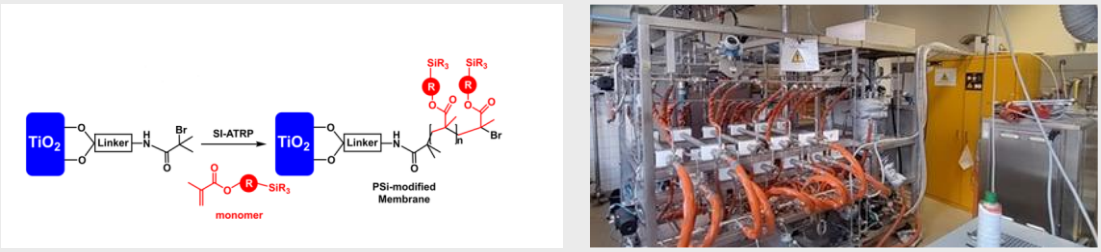
## THE CHALLENGE

Building further on a previous collaborative project, the Mem4SusDiary project aimed to demonstrate an efficient NF process using modified ceramic membranes to pre-concentrate and partially demineralize milk whey before the IEX step. This NF process is intended to replace an RO process at a specific FrieslandCampina production site, in such a way that the demineralized whey output per batch can be increased, and the chemical consumption and wastewater generation associated with IEX can be reduced, resulting in significantly lower production costs per kg of product.

Experimental development included systematic testing of a variety of modified ceramic membranes synthesised in house at VITO on a representative milk whey mixture, and benchmarking against commercial polymeric NF membranes. After these screening trials, the best performing modified ceramic membrane was scaled up to multi-channel modules, and proof-of-concept-trials were carried out under industrially relevant conditions.



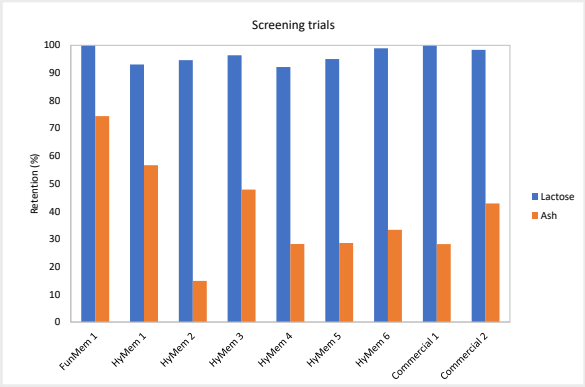

Schematic representation of modified ceramic membrane (left) and picture of modification pilot installation (right) as used in Mem4SusDiary project.

## THE RESULTS

VITO synthesised a variety of customized single-tubular modified ceramic membranes using the patented Surface Initiated – Atom Transfer Radical Polymerization (SI-ATRP) technique applied on ceramic UF supports (HyMem). Furthermore, several Grignard-grafted ceramic membranes with tailored surface chemistries (FunMem), also developed at VITO, were prepared. These innovative modified/functionalized ceramic membranes were tested on a representative model milk whey stream under industrially realistic conditions and benchmarked against selected commercial polymeric and ceramic NF membranes.

Screening trials showed high lactose and protein retention for several modified ceramic membranes, combined with a relatively low salt retention and competitive flux performance. One specific HyMem membrane demonstrated clearly lower salt retentions than the benchmark membrane, combined with a similar flux and comparable irreversible fouling propensity. This membrane was chosen for scale-up and proof-of-concept testing.

Upscaling of the multi-step HyMem modification procedure from small single tubes to 19-channel membranes of 50 cm length, what was never tried before for this specific membrane type, was realised successfully. A proof-of-concept concentration test up to about 80% permeate recovery (concentration factor 5) was then carried out with this multi-channel membrane. While the lactose retention and flux were found to be somewhat lower compared to small scale lab testing, chemical cleanability was excellent.




Retention profile of selected experimental and commercial NF membranes.

## CONCLUSION

The following promising conclusions can be drawn from the Mem4SusDairy project:

- Various modified ceramic membranes show low and sharp cut-off, combining high lactose retention >98% and low salt retention, allowing for efficient recovery of lactose and milk proteins (>90%, KPI 1), hence efficient demineralization of milk whey (>50%, KPI 2), competitive to polymeric reference membranes.
- Best performing modified membrane (HyMem) was successfully scaled up to 19-channel geometry for the first time.
- Compared to small scale screening trials, multi-channel HyMem membrane exhibited somewhat lower lactose yield and flux performance (approx. 1.3 L/hm$^2$bar at start of concentration, KPI 3), however flux recovery after repeated filtration-cleaning cycles was excellent (>85%, KPI 4).

## TECHNIQUES USED

In Mem4SusDiary the following services and capabilities of the INNOMEM OITB, all available at INNOMEM partner VITO, were used:

- Synthesis of low cut-off hybrid NF membranes by tailored modification of ceramic support membranes.
- Upscaling of modification procedure to intermediate scale multi-channel membranes.
- Screening and proof-of-concept testing of modified ceramic and reference polymeric NF membranes under realistic conditions using dedicated crossflow installations.
- Extensive analysis of samples (lactose, protein, salts, etc.).

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