# Membrane cascades for production of high quality whey derived products

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# How to separate the inseparable

"You can never solve a problem on the level on which it was created."
Albert Einstein

- Separation strategies
- What if the molecules are look-a-likes ?
  - Solve it at a different level
- Membrane cascades
  - Design
  - Yield and Purity
  - Flexibility
  - Pilot plant tests
- Membrane cascades uncouple Yield and Purity

# Currently available industrial routes

## Precipitation; Membrane fractionation & Chromatography

### Precipitation

Fractionation
- Yield ✓
- Purity ✓/✗

Processing aid YES

Tuneable ✗

Costs: LOW

### Membranes

Fractionation
- Yield ✓ /✗
- Purity ✓ /✗

Processing aid Water

Tuneable ✓

Costs: FAIR

### Chromatography

Fractionation
- Yield ✓
- Purity ✓

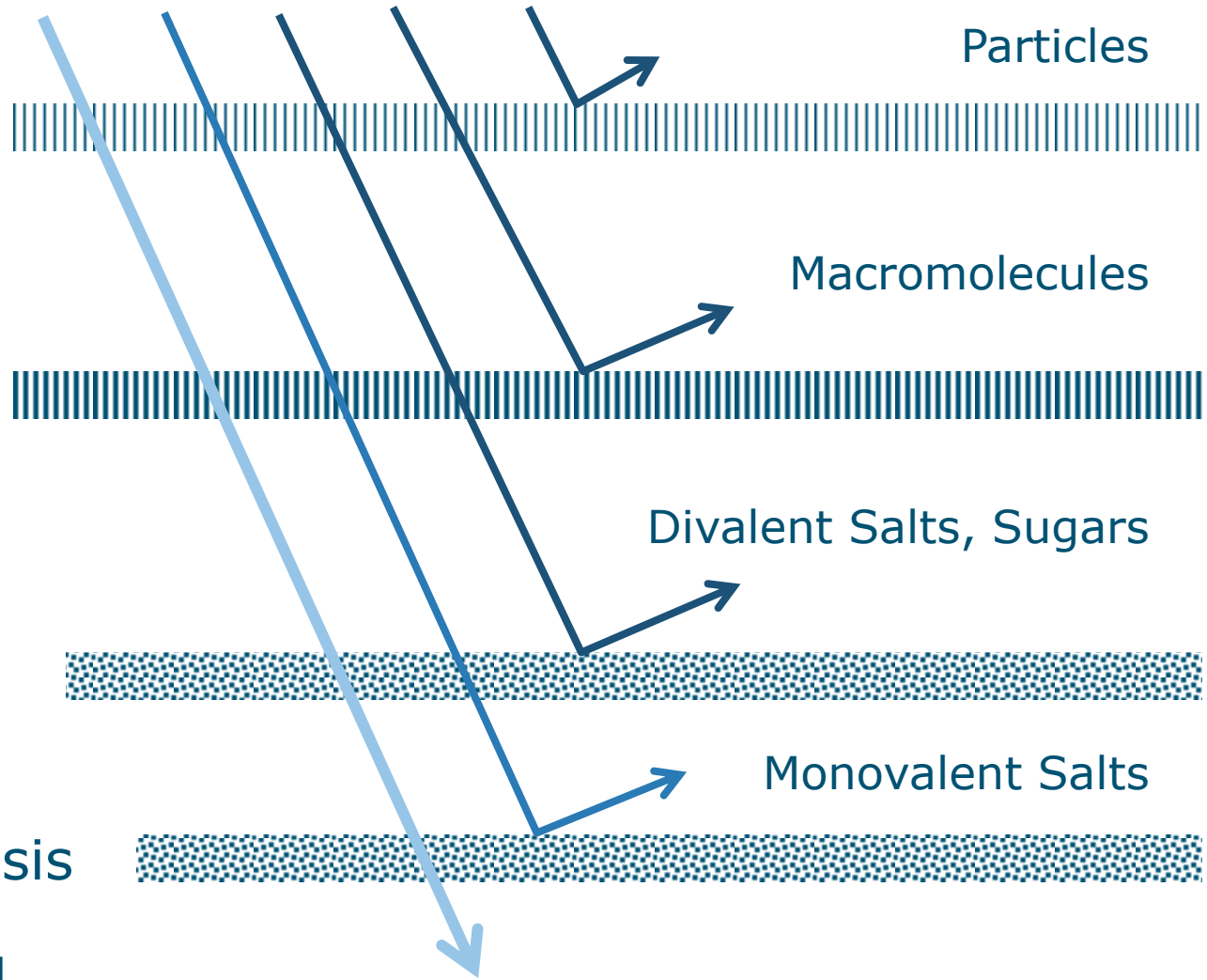
Processing aid Water

Tuneable ✓

Costs: HIGH

# Current use for fractionation

- Microfiltration
  0.1 – 10 µm
- UltraFiltration
  1 – 100 nm
- NanoFiltration
  0.5 – 5 nm
- Reverse Osmosis



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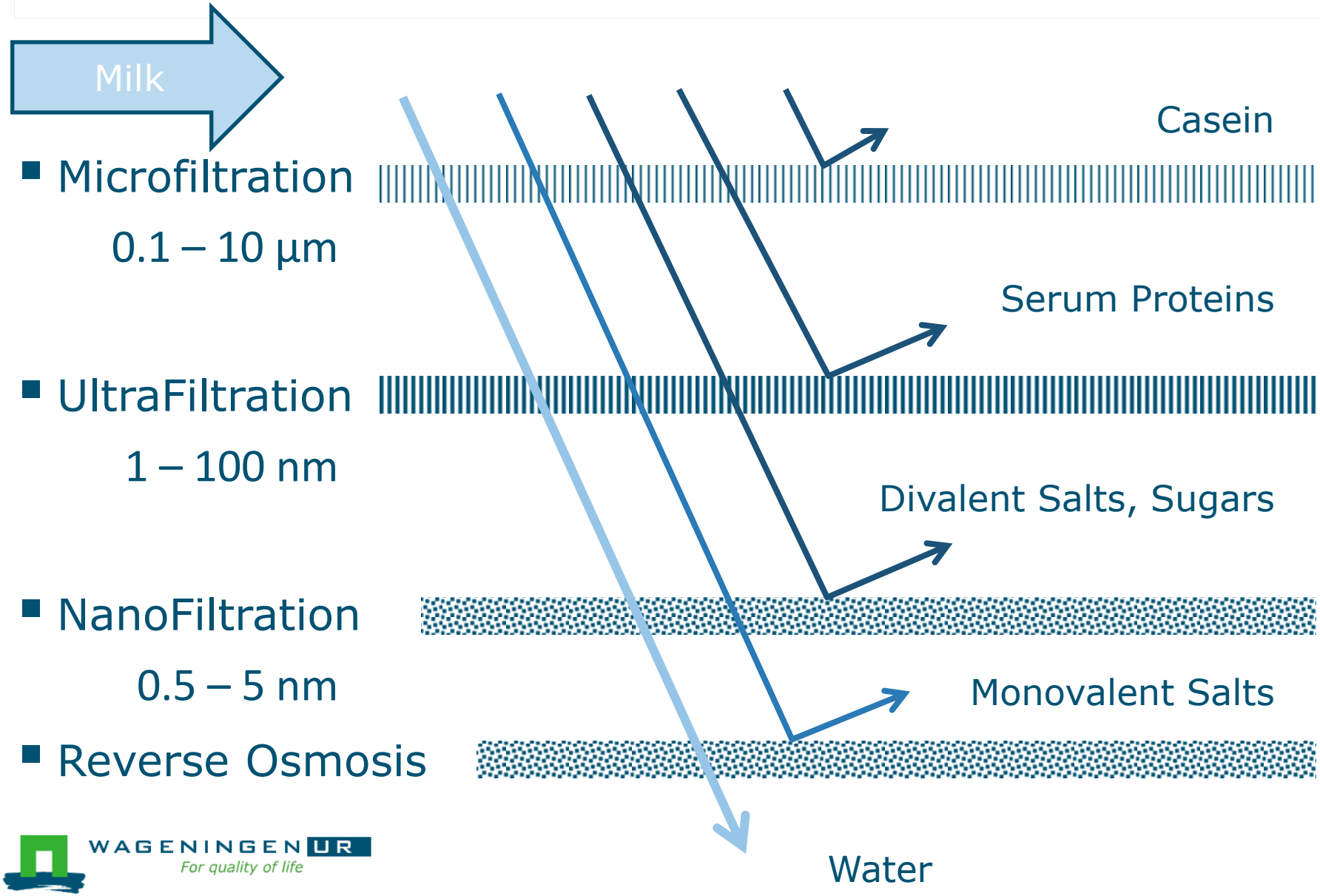

# Can we fractionate sugars – e.g. GOS

## Unfortunately not: the selectivity is too low

GOS

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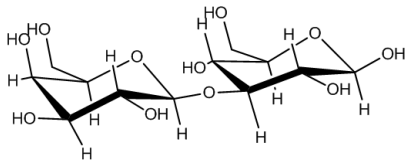
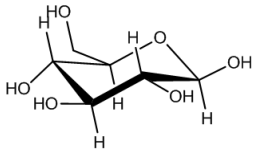
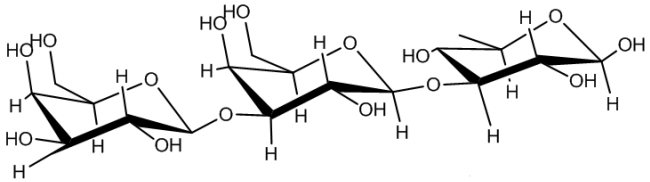






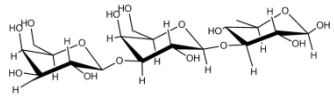
**0.6 nm** tri-sugar

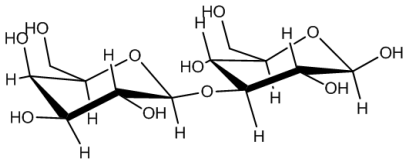
- NanoFiltration

0.5 – 5 nm

**0.54 nm**

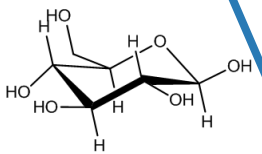
**Find a better membrane ?**





mono and di-sugar

**0.42 nm**



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# Membrane cascade

## Find a better system

"You can never solve a problem on the level on which it was created."
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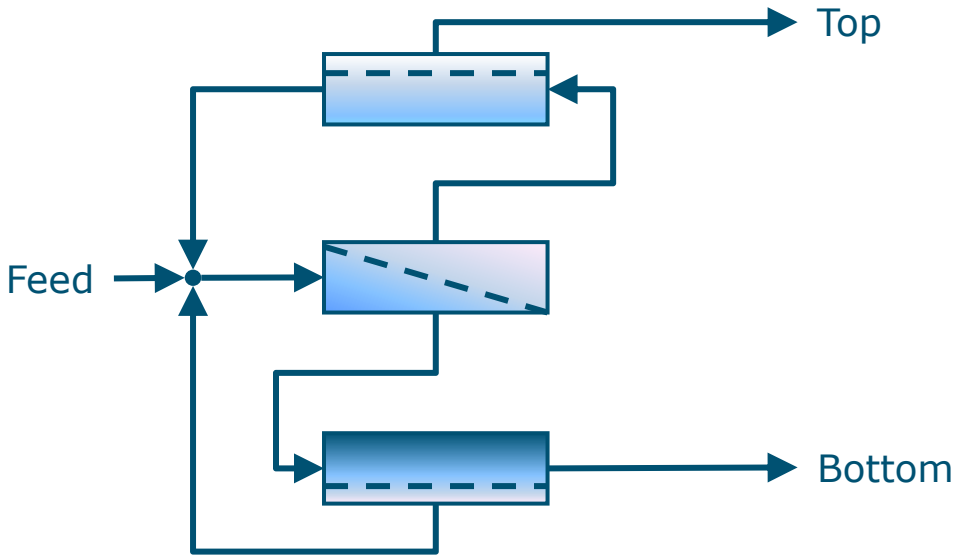
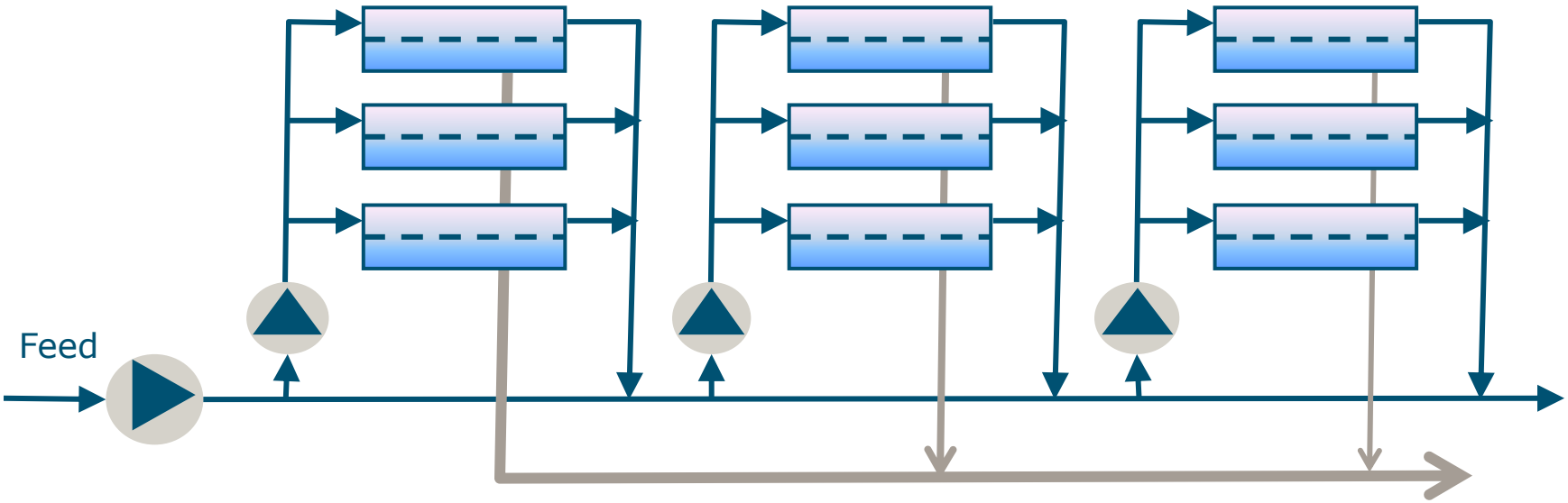
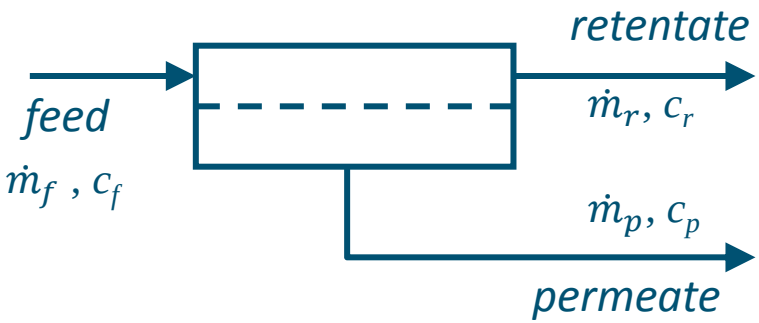
- Keurentjes (Chem. Eng. Sci. 47 (1992) p1561)
- Rautenbach (Membrane Processes, Wiley, New York (1989) Chap. 6)
- Lightfoot (Sep. Sci. Technol. 40 (2005) 739-756)
- Van der Bruggen (Sep. Pur. Technol. 80 (2011) 600-609).



# Membrane configuration: state of the art

## Find a better system

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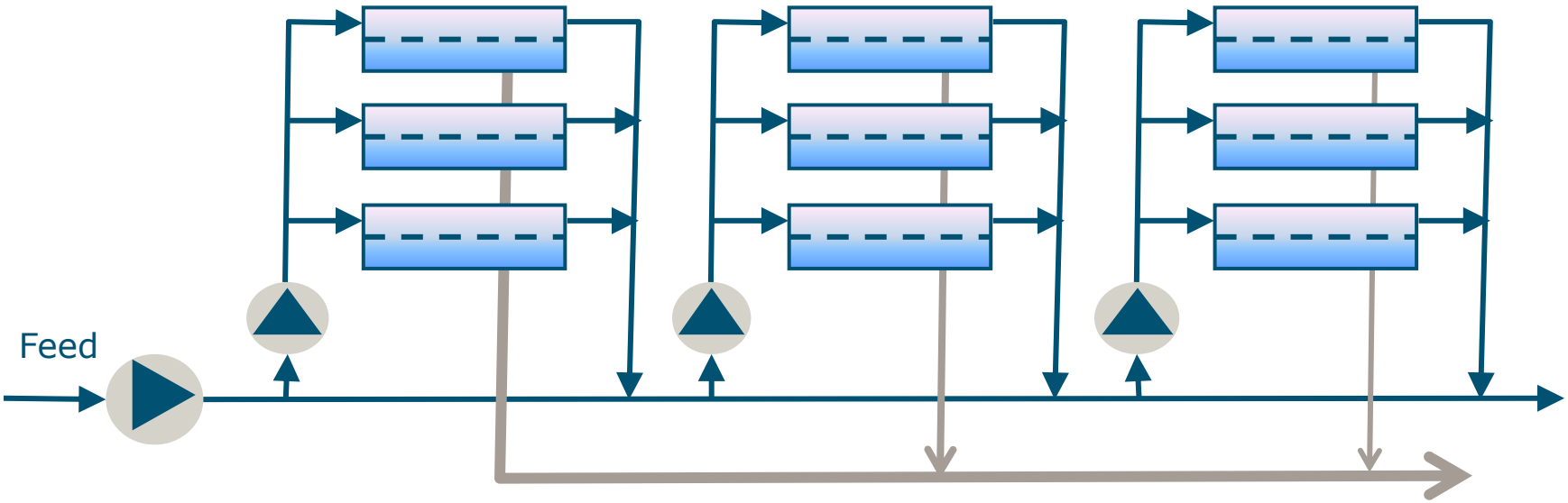
# Conventional System → Cascade



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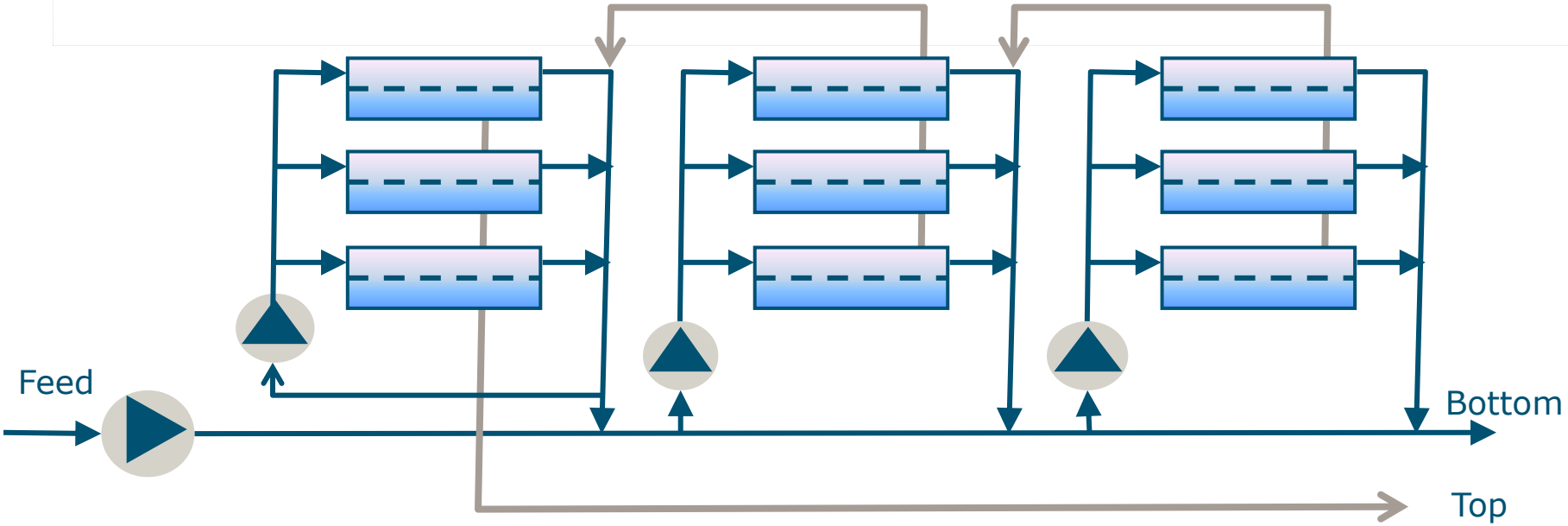


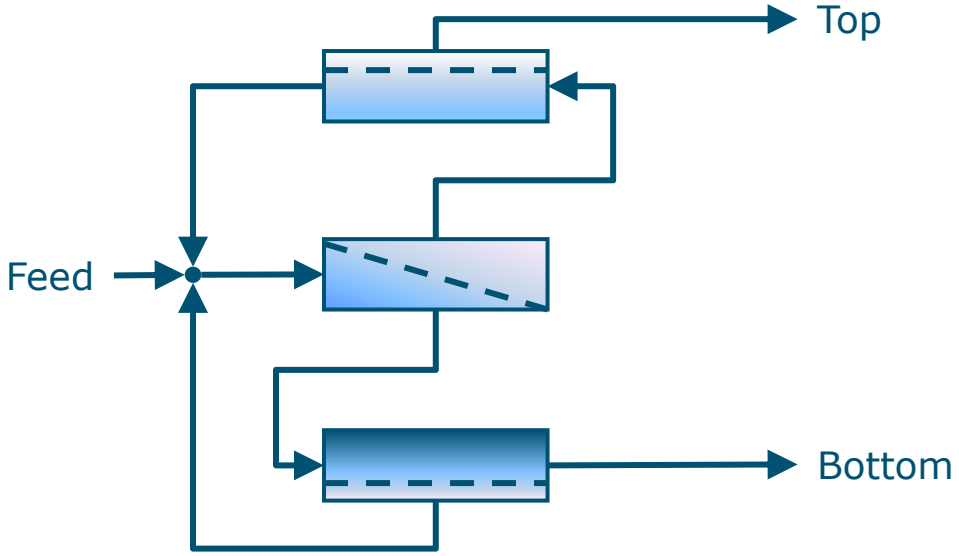

# Membrane cascade

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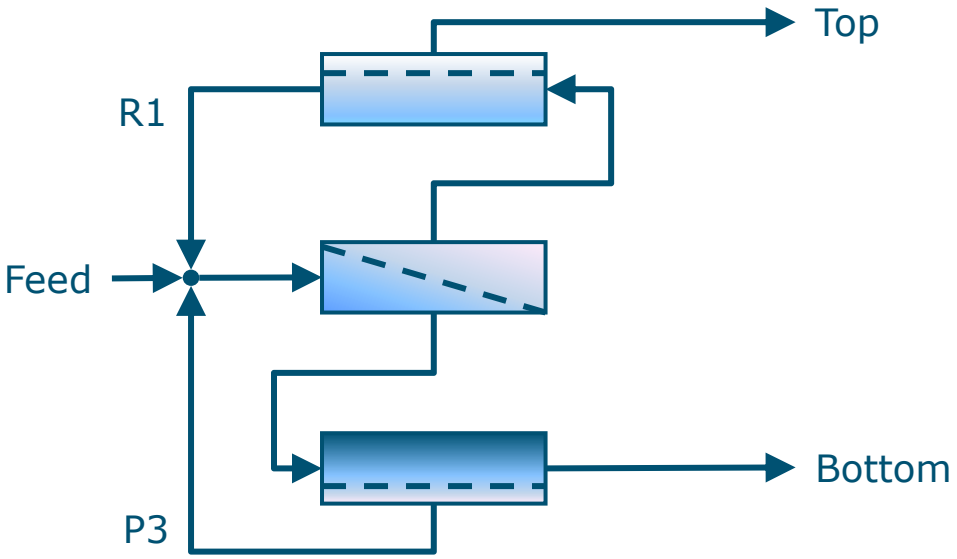
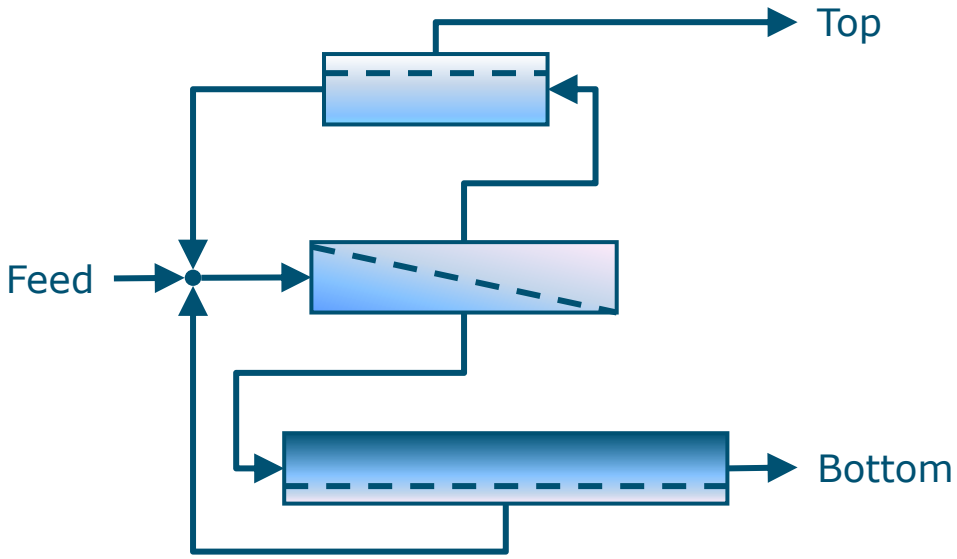
Lightfoot constraint:
Ratio F = R1 = P3



# Membrane cascade

- Design
  - Constraint: Ratio F = R1 = P3
  - Membrane Area
- Yield and Purity

- Flexibility
- Pilot plant tests



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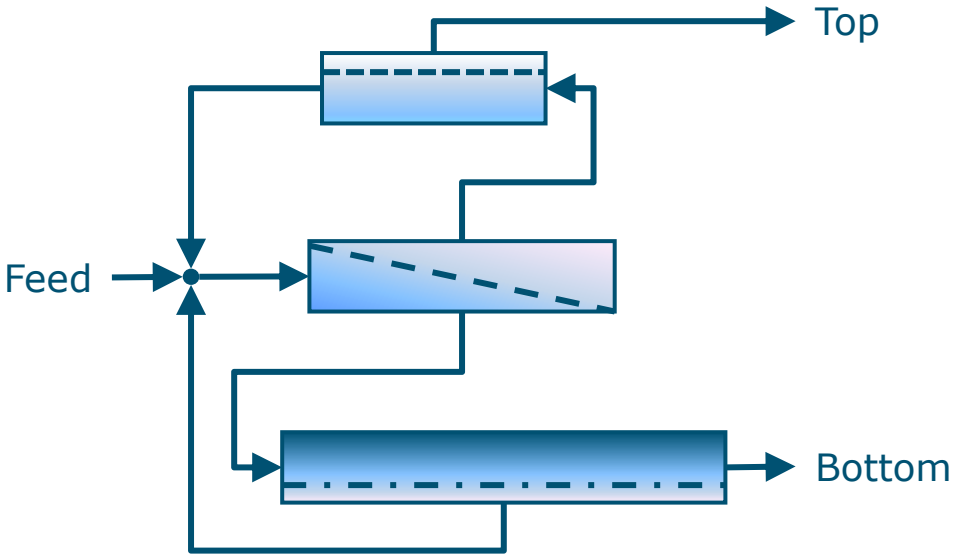
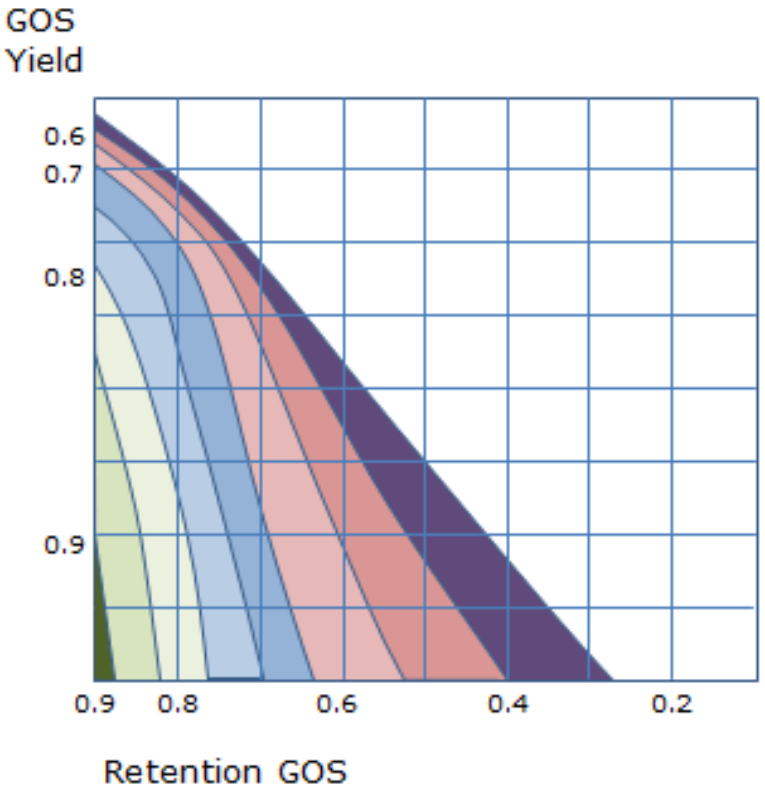


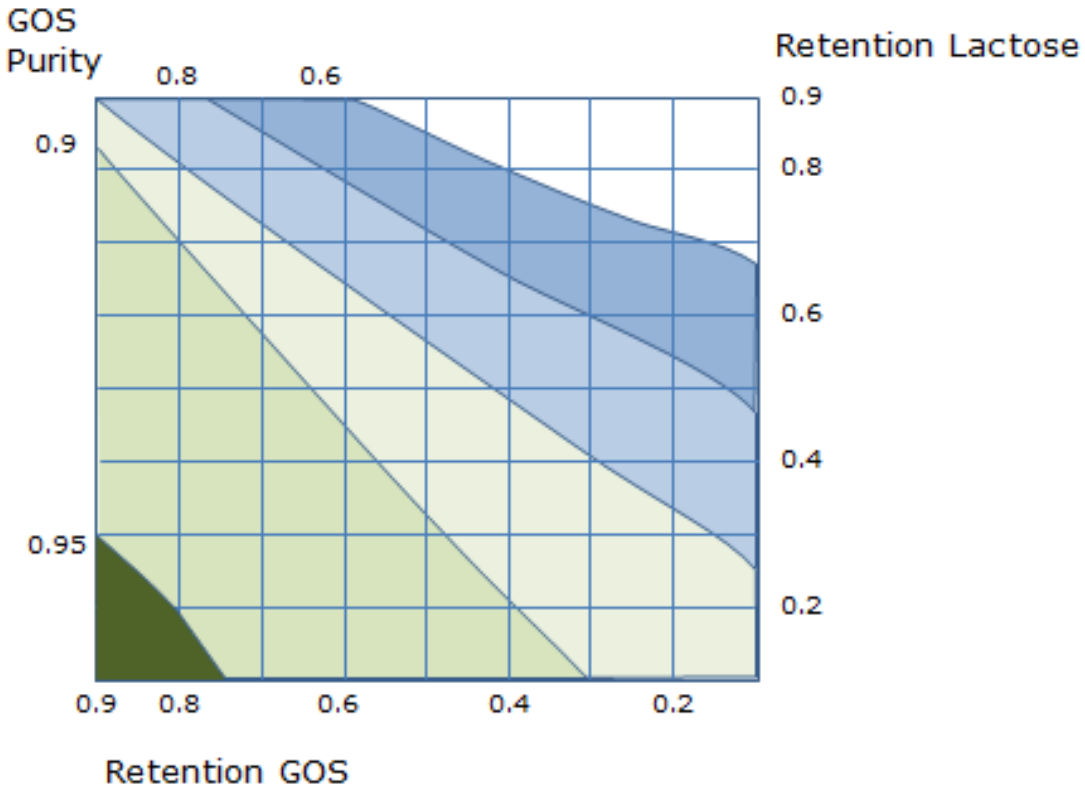
# Membrane cascade

- Pilot plant tests

# Design: Window of Operation

## Membrane performance determines the relation between Yield and Purity




For the fractionation of DP2 and DP3, →

Retention GOS > 0.9

Retention Lactose < 0.2

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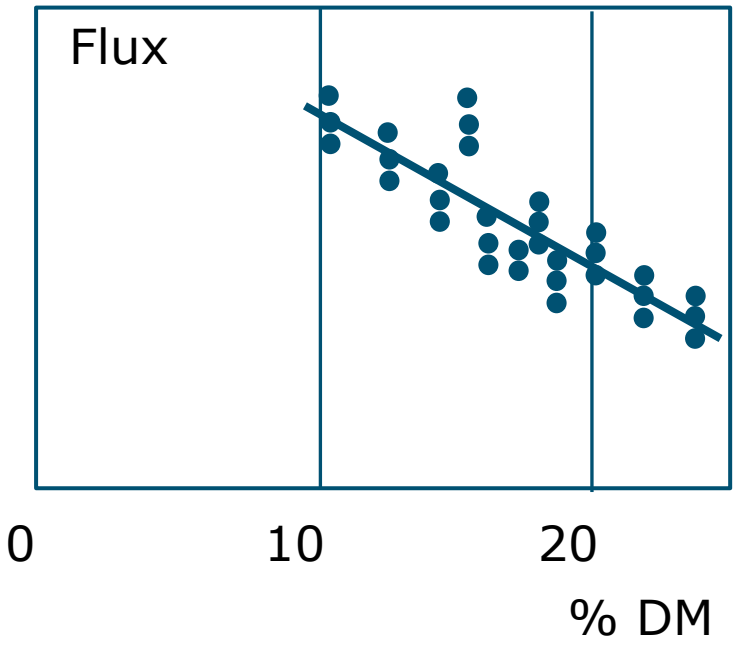
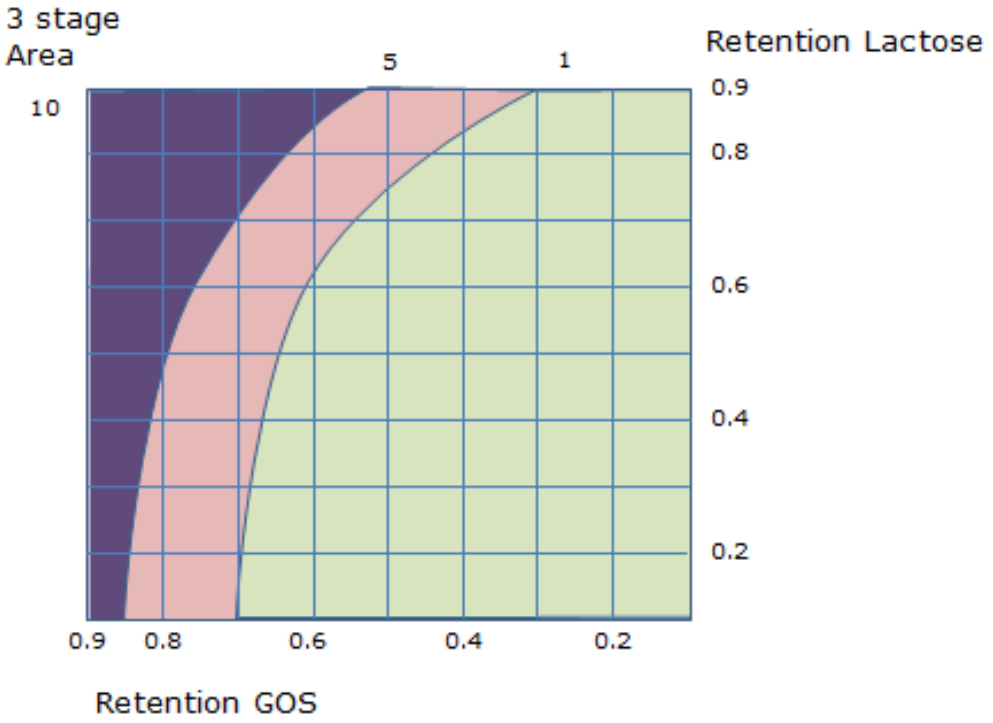
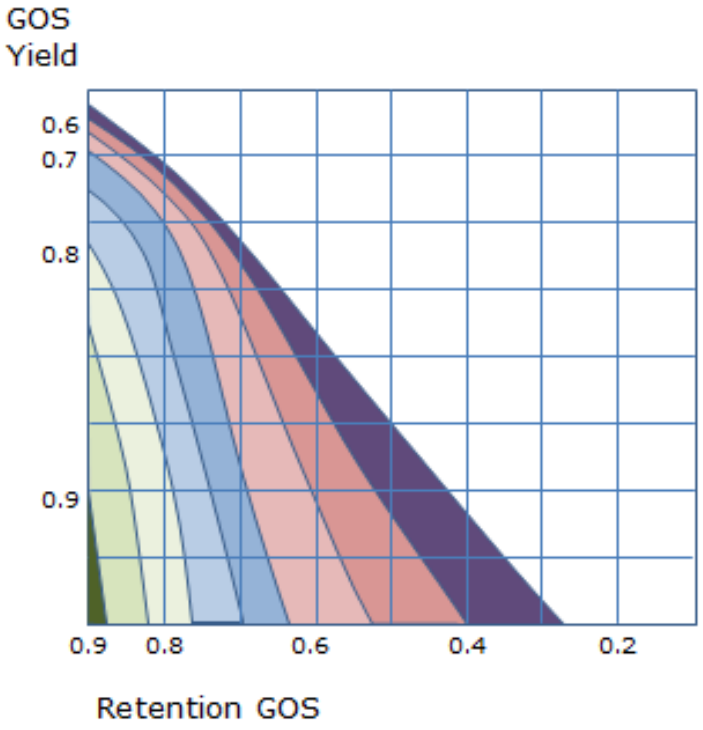
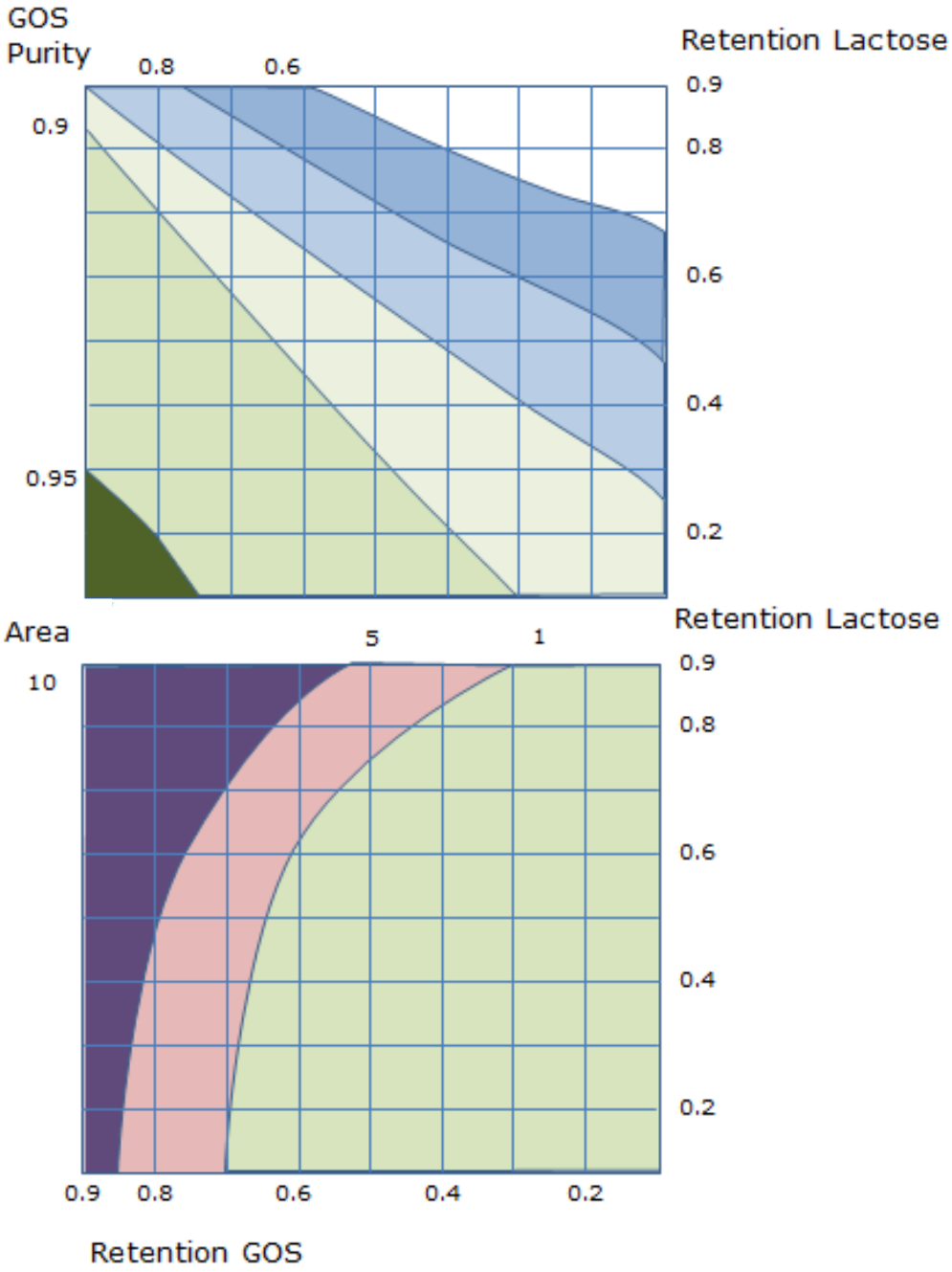
# What will the size be of such a system

## That depends on the concentration



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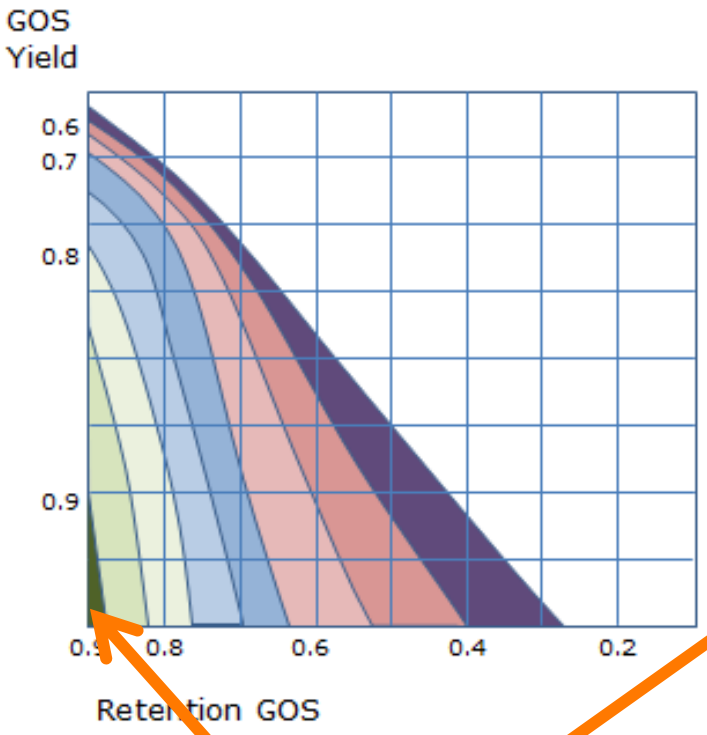
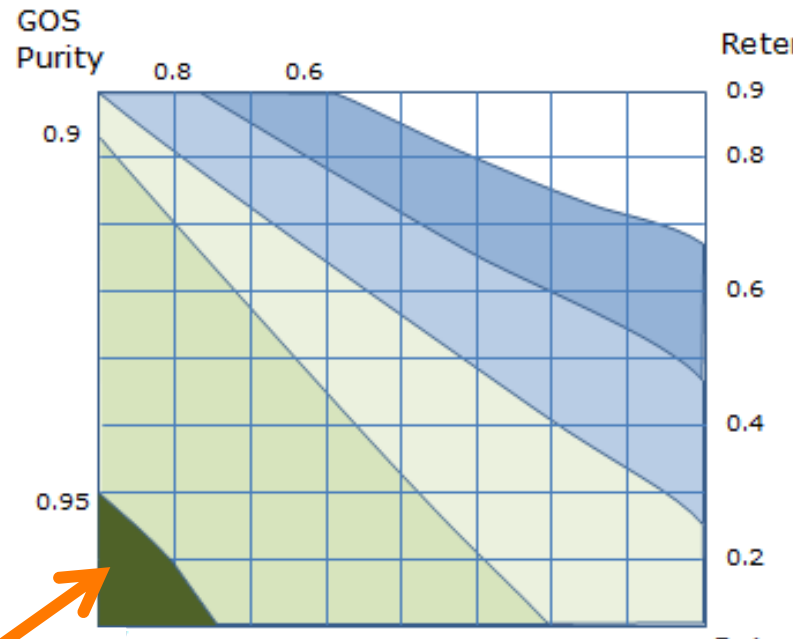
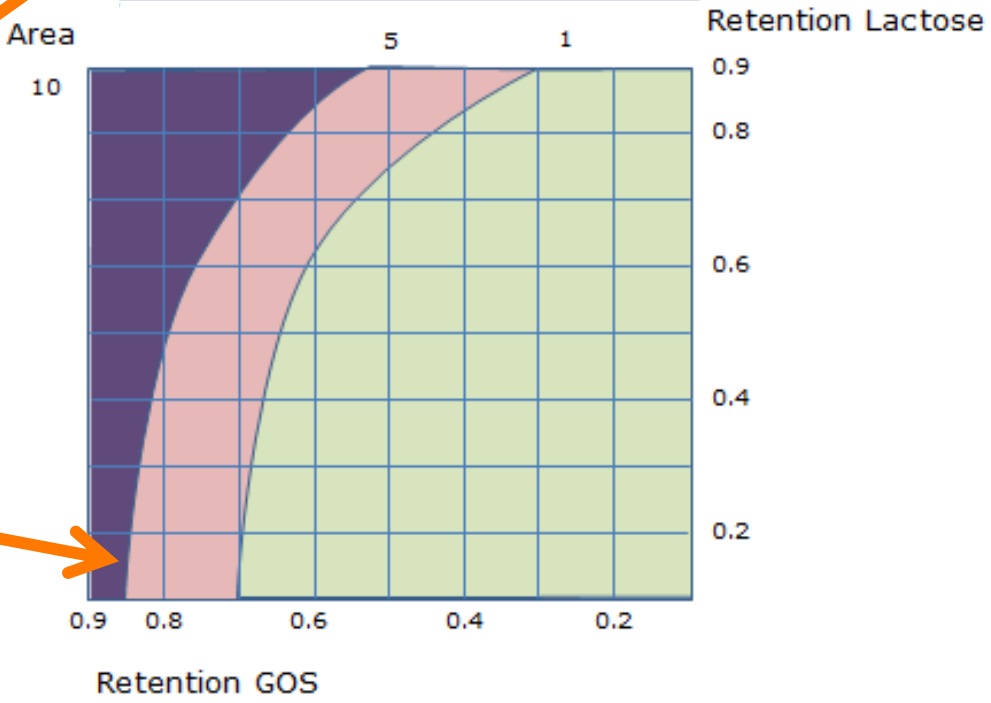



Due to the low flux,

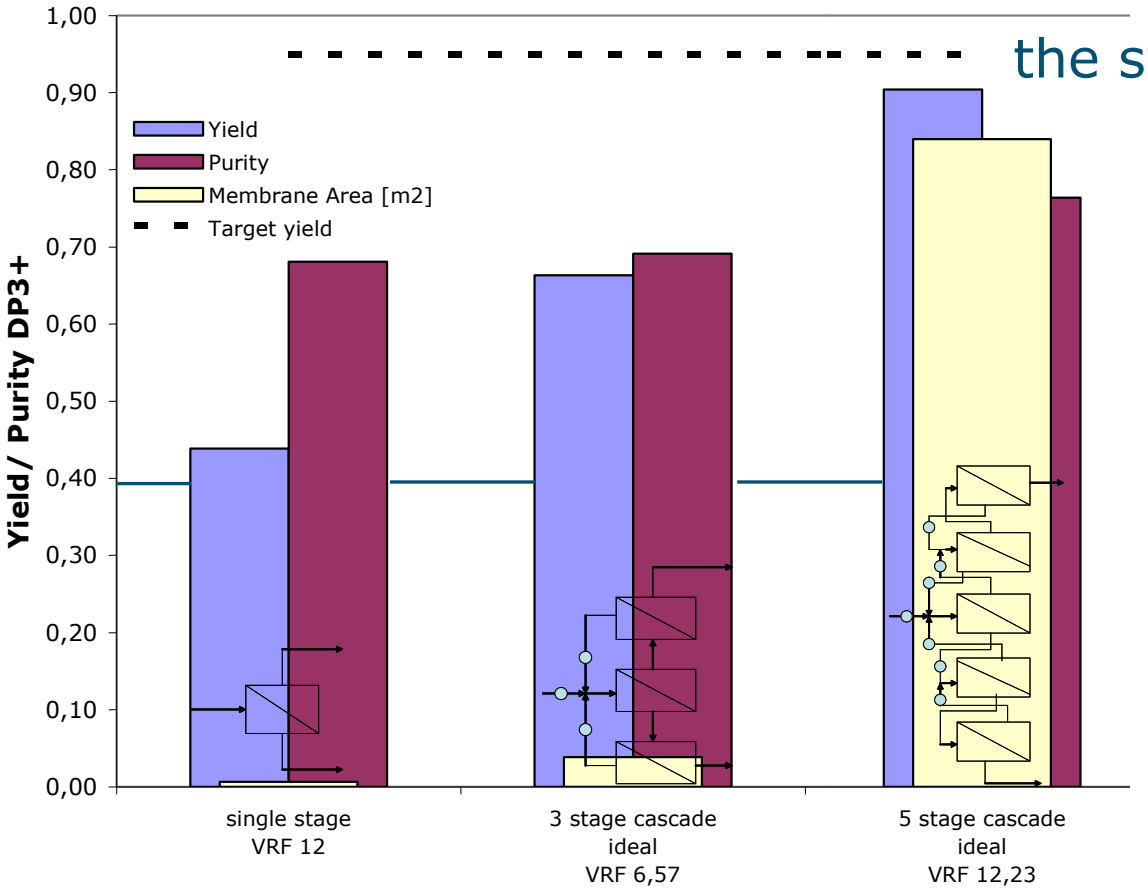
the system becomes large

# Calculated Yield and Purity

## for the best membrane we could get.

Due to the low flux,

the system becomes large

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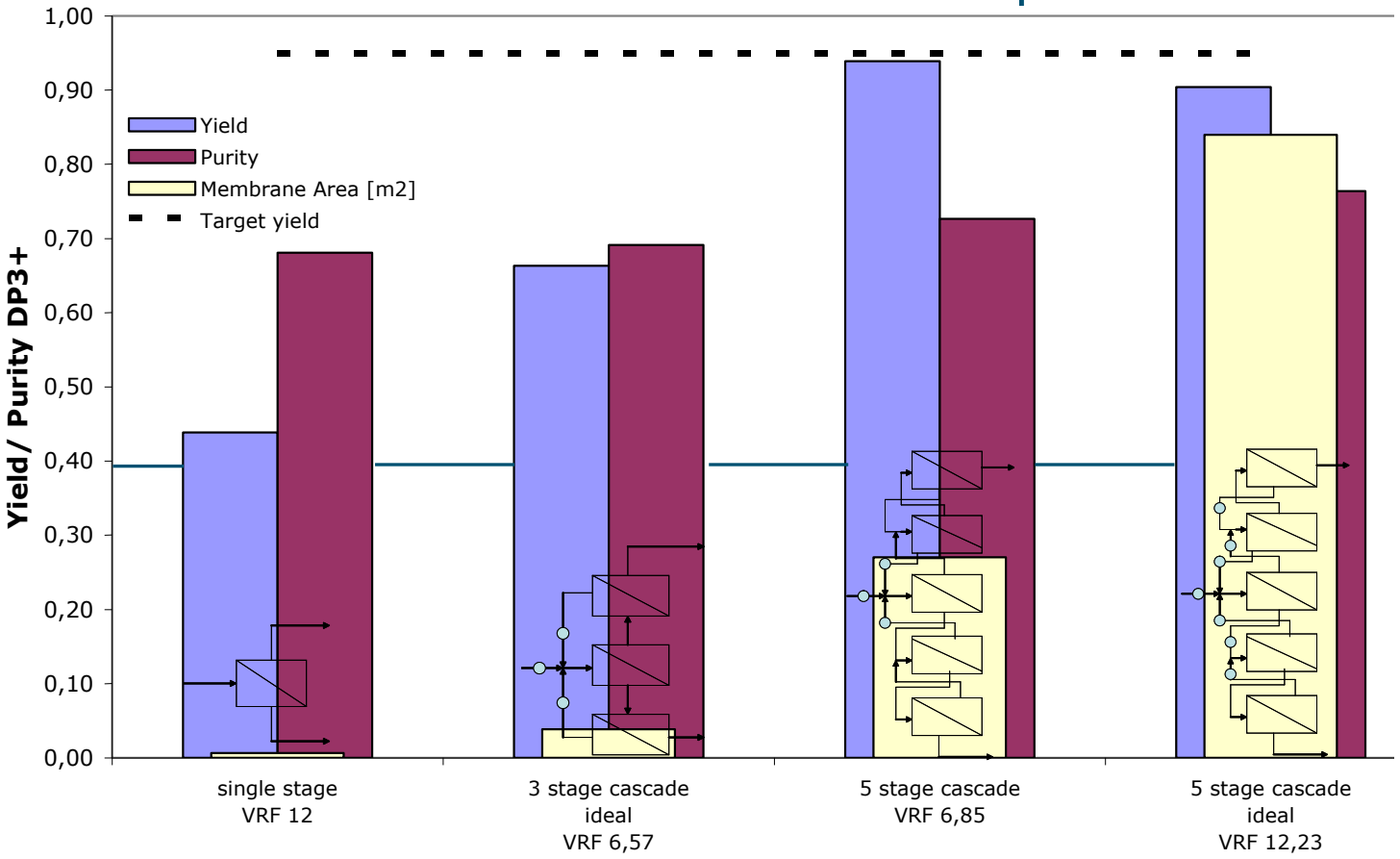
# Calculated Yield and Purity

## for the best membrane we could get.

### Optimize membrane area



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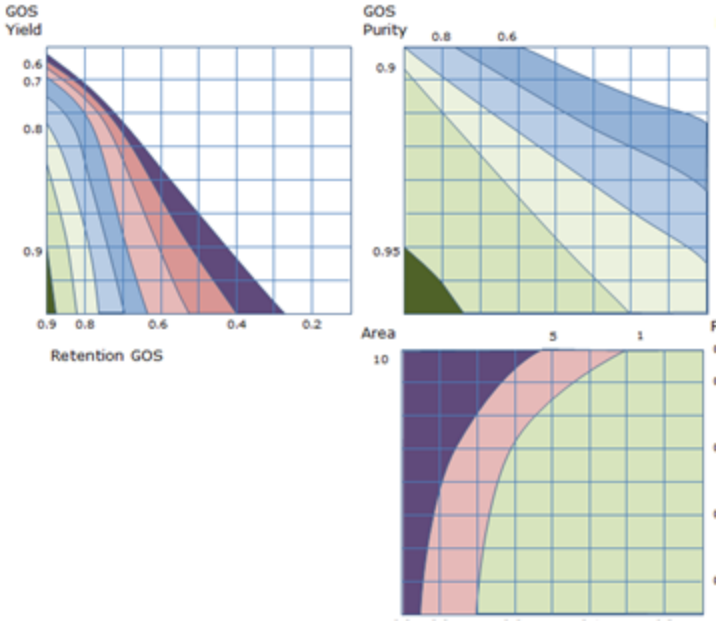
- Pilot plant tests



# Pilot test:

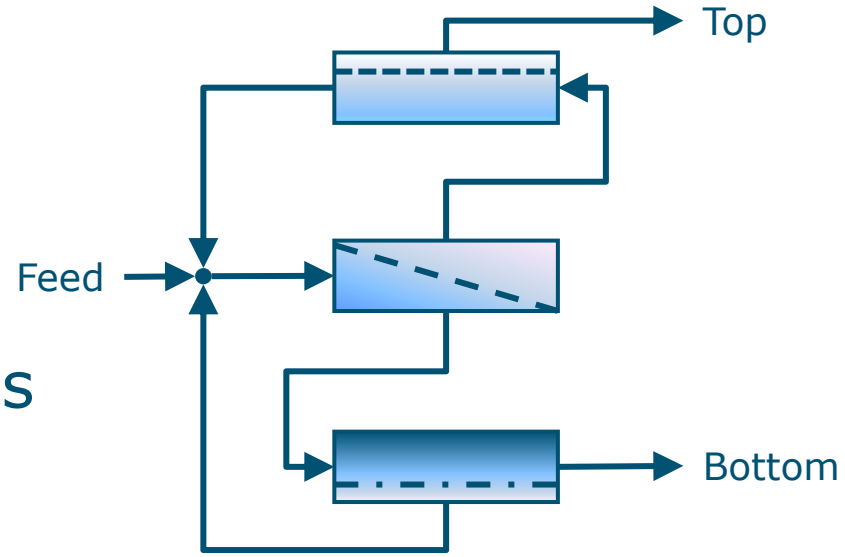
## 3 stage system tested at the Wageningen University

Flexibility

2 types of membranes

- 1 kD
- 2.5 kD

Different pressure settings to ensure ideal cascade




The 3 stage system was funded by the ISPT, the Institute for Sustainable Process Technology

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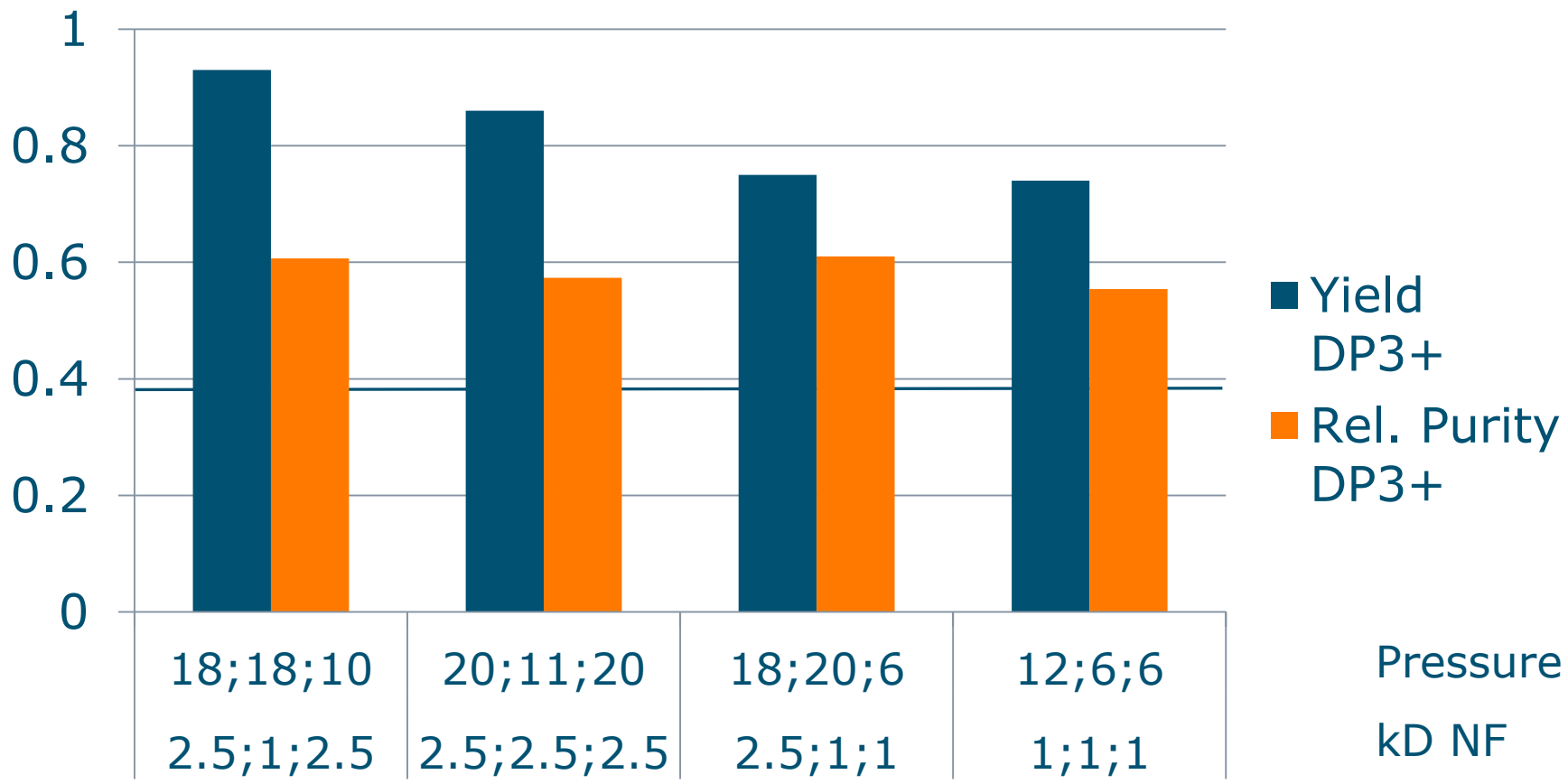
ISPT

# Pilot test GOS:

## 3 stage system tested at the Wageningen University

### Flexibility

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N.V. Patil, T. Schotel, A.E.M. Janssen, R.M. Boom, to be published

# Pilot test GOS:

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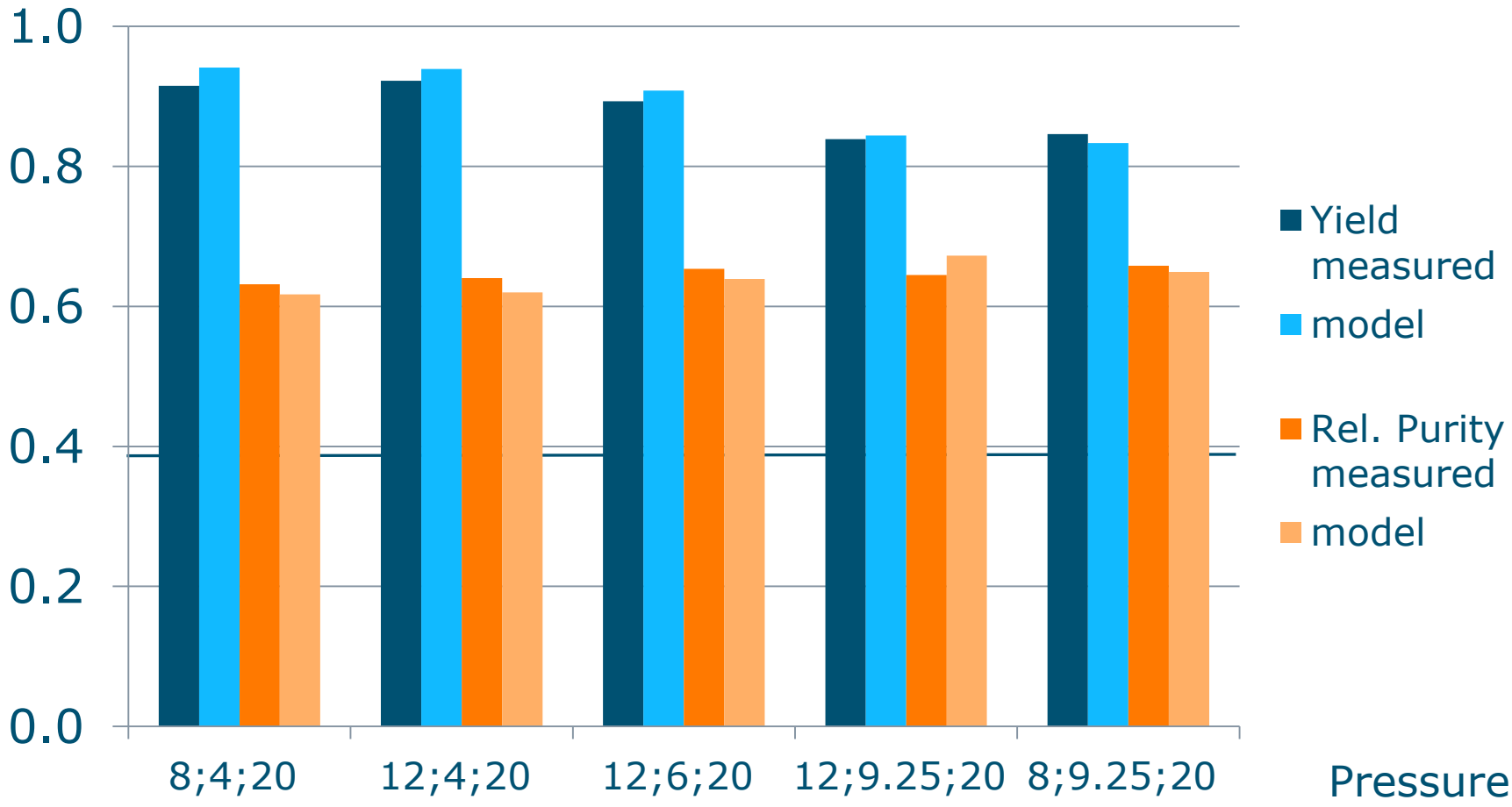
## Model validation

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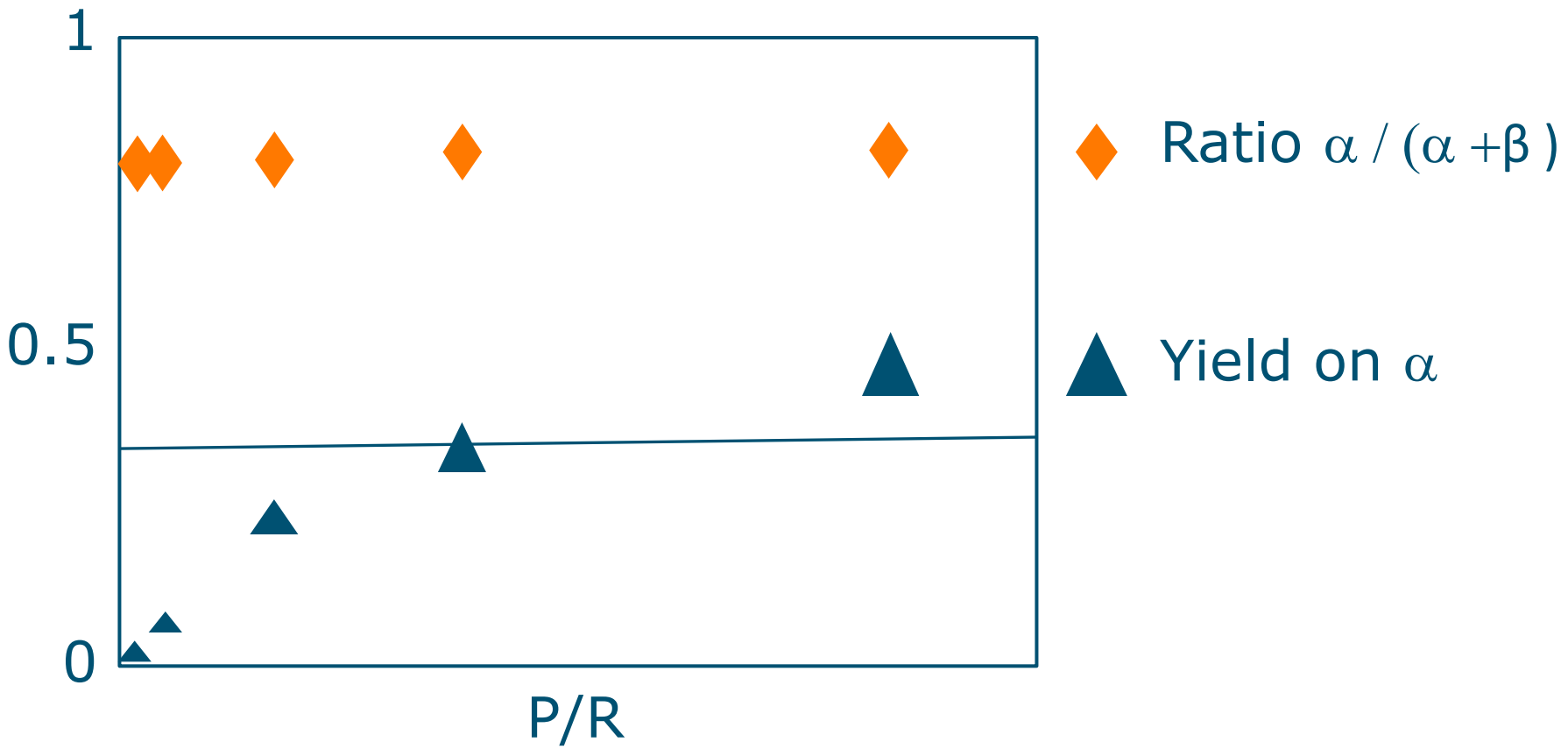
# WPI: α-Lactalbumin and β-Lactoglobulin

## 3 stage system tested at the Wageningen University




Separation of whey proteins using cascaded ultrafiltration
N.V. Patil, A.E.M. Janssen, R.M. Boom.
Accepted for publication by Sep. Sci. and Technol.

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# How to separate the inseparable

## A welcome addition to the engineers toolbox

- Membrane cascades adds to the engineers toolbox
  - Model validated, design is possible
  - Yield and Purity are decoupled
  - Flexibility, hence modelling is essential

- For GOS
  - Unfortunately, difference DP2 and DP3 is too small
  - It works for α-Lactalbumin and β-Lactoglobulin

- Membrane cascades uncouple Yield and Purity

*Albert van der Padt, Joost Hennen, Anja Janssen*