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BIOCON-CO_2

Technologies & tools for downstream processing

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Downstream processing (DSP)

- Bio-based products must be efficiently recovered and purified from the media where they are produced to be used in their final applications.
- Product recovery and purification, known as **downstream processing**, is often a complex task accounting for a significant share of the process costs (up to 75%).
- CO_2 (gas)-derived products usually are present at one to two orders of magnitude lower than their sugar-derived counterparts.
- Necessary **efficient, cost-effective and non-energy intensive** downstream processes for industrial feasibility.

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WP6. Downstream and validation of the obtained products

Objectives

- Develop downstream strategies applicable to the target molecules (C3-C6 alcohols, PHB, formic and lactic acid), taking into account the characteristics of the effluents from WP3-5 (fermentation and biocatalysis).
- Validate the purified products obtained from downstream by the end-users, both physico-chemically and in their main market applications.

A tool for optimum downstream processing
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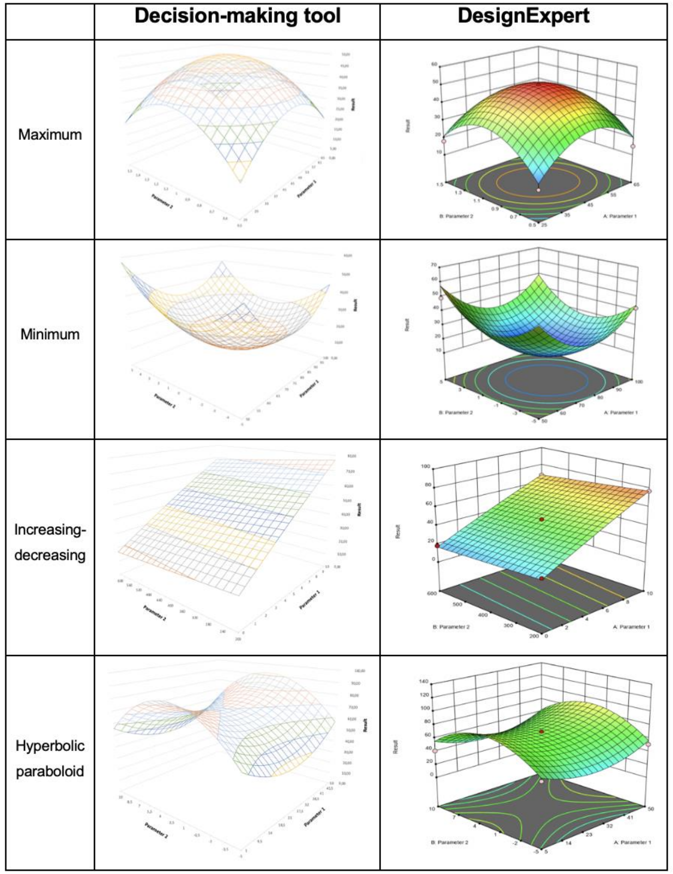
During BIOCON-CO2 project a DoE based tool for design and assessment of downstream separation routes has been developed:

- User-friendly
- Up to 4 variables with RSM and optimal conditions search
- Open source
- Tutorial of tool usage
- Validated against conventional softwares



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Downstream for C3-C6 alcohols
Pervatech BV

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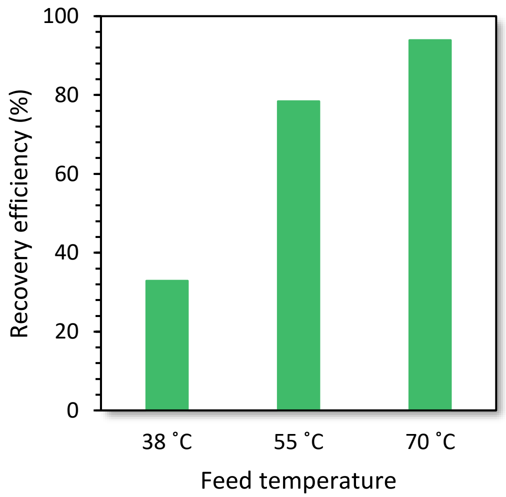
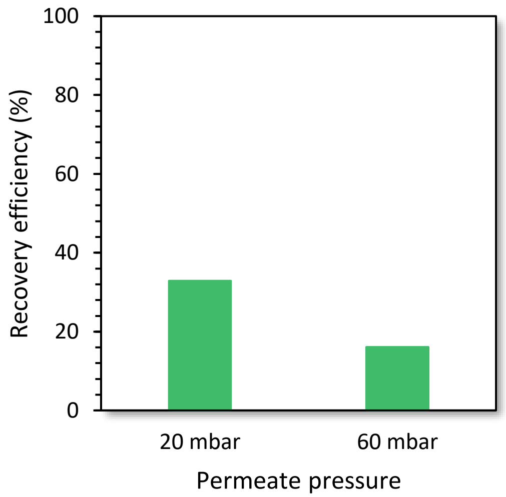
Optimization of Pervaporation Process Parameters

- Artificial medium based on effluent composition
- Recovery efficiency: percentage of alcohols recovered from effluent
- Increase in T_{feed} and $P_{permeate}$ results in a higher driving force
- Optimized process parameters: 70 ˚C and 20 mbar

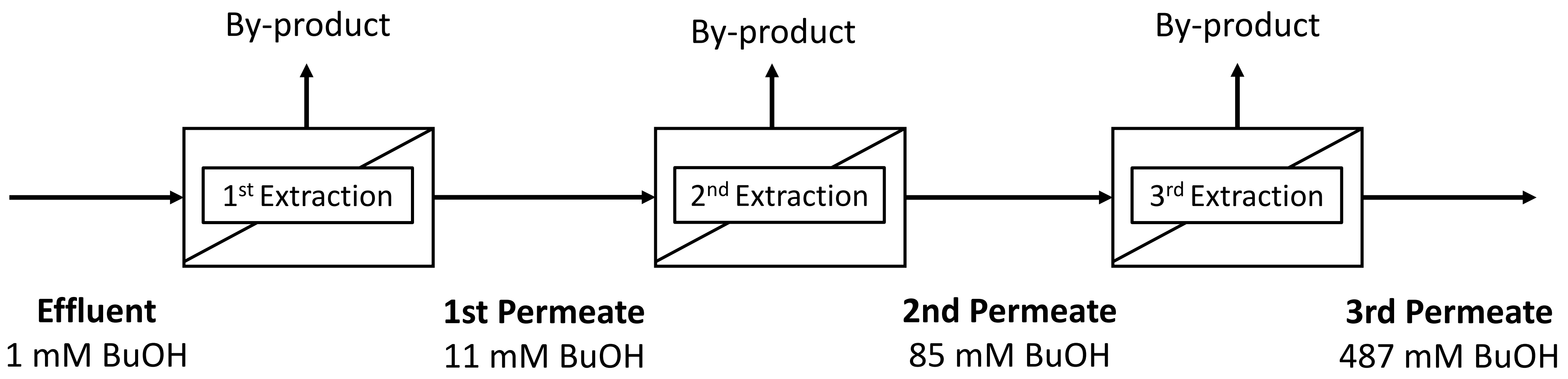




Downstream for C3-C6 alcohols
Pervatech BV

Overall Process

- Verification with real effluent from BBEPP for the 1st extraction
- Multiple extractions to increase butanol concentration to 400 mM



$$\mathbf{RE_{1\text{-}BuOH} = >90\%}$$

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Downstream for PHB and lactic acid

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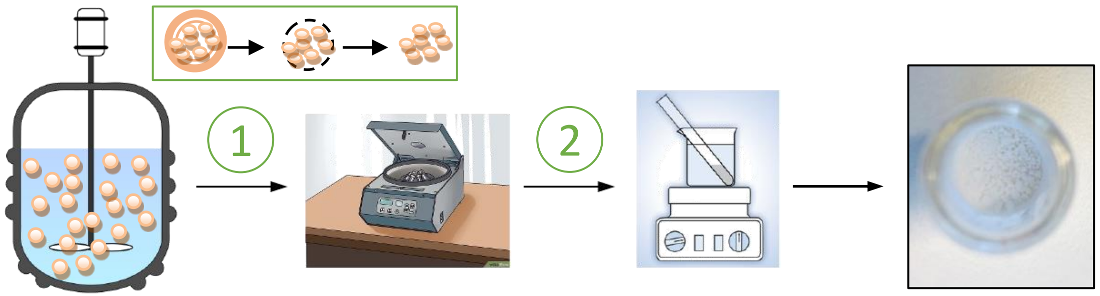
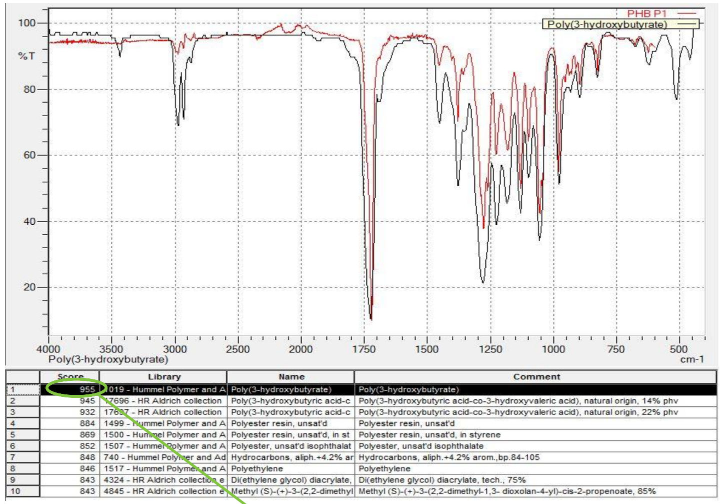
PHB downstream (80% w/w intracellular product)



1. Centrifugation
2. Washing with water and acetone and solvent evaporation



FTIR: 95.5% match PHB

Lactic acid downstream (22 mM Lactic acid)

Fermentation broth → Ultrafiltration (0.03 µm) → Nanofiltration 150-300 Da → Reverse Osmosis → Retentate RO - - → Lactic Acid + EtOH + salts

Ultrafiltration (0.03 µm) → Retentate UF

Nanofiltration 150-300 Da → Retentate NF

Reverse Osmosis → Permeate RO

Conc (g/L)	NF	RO
Retentate	3,17	2,81
Permeate	1,48	0,06
Rejection (%)	50	>99

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Downstream for formic acid

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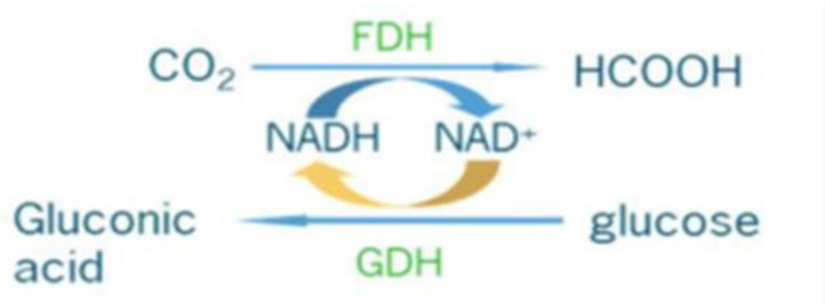
Formic acid effluents

- Synthesis of formic acid from CO_2 by a coupled biocatalytic reaction (WFBR - Wageningen Food & Biobased Research).



- As a result of this reaction, aqueous effluents are produced characterized by the presence of equimolar concentrations of formic and gluconic acids.

Formic acid effluent composition	
Compound	**Concentration**
Formic acid	2 g/L
Gluconic acid	9.8 g/L

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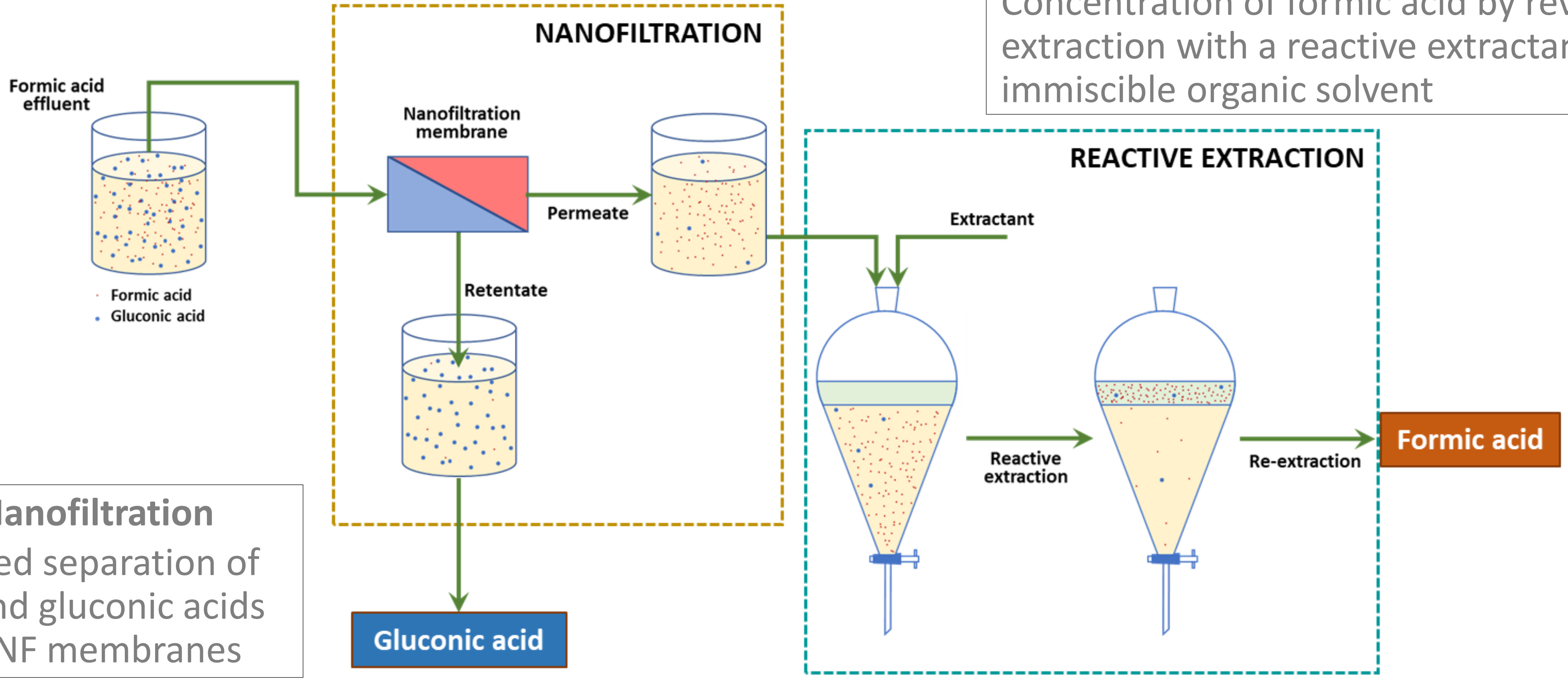
Downstream strategy

Step 2: Reactive extraction
Concentration of formic acid by reversible extraction with a reactive extractant in an immiscible organic solvent



Step 1: Nanofiltration
MW-based separation of formic and gluconic acids through NF membranes

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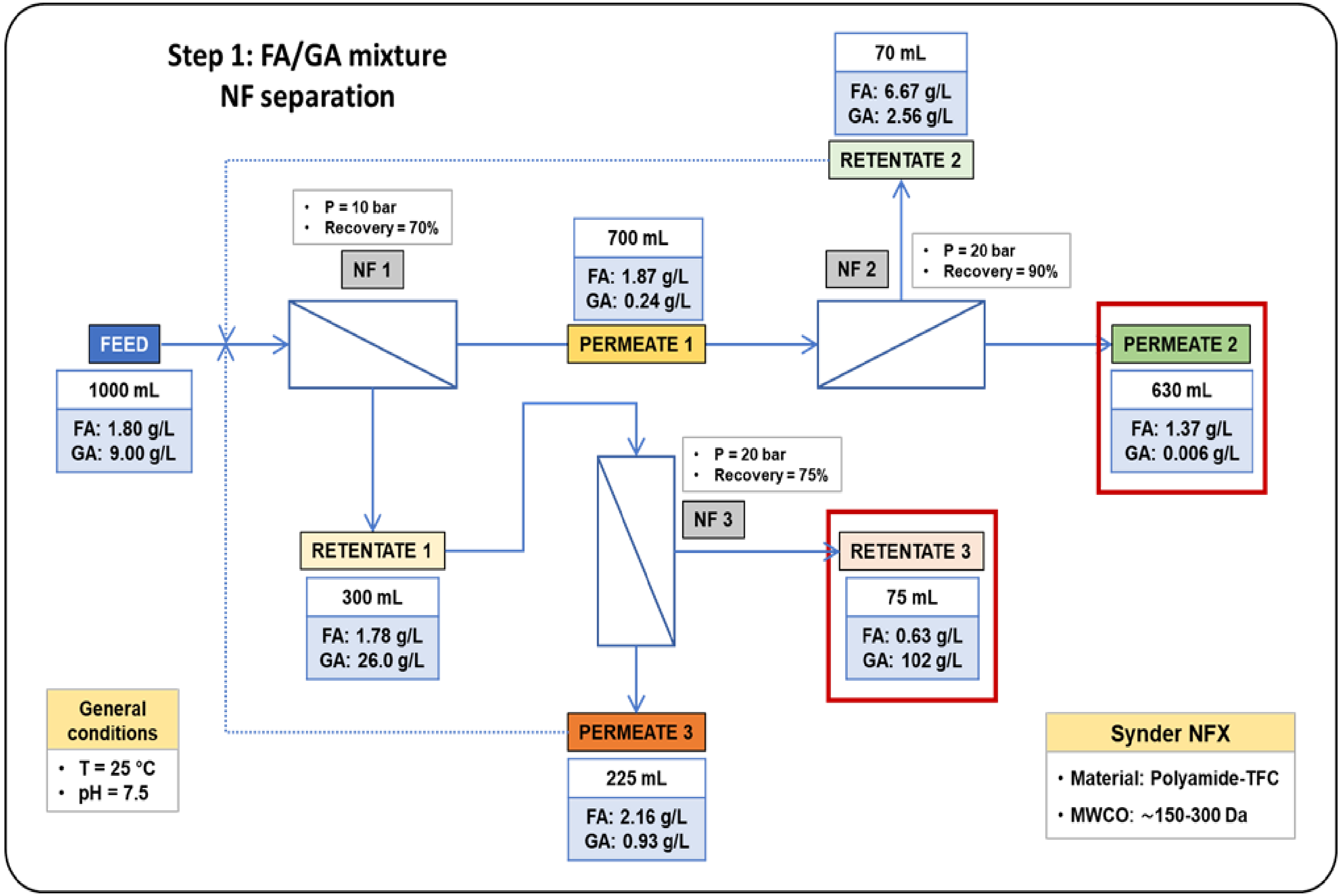
Step 1:
Nanofiltration



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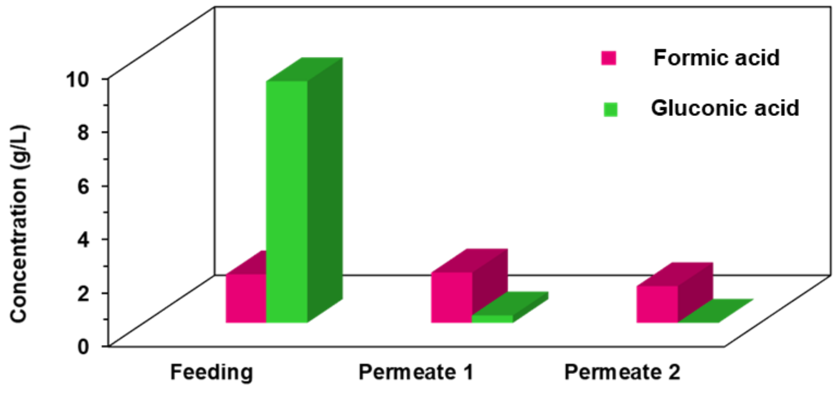
Step 1:

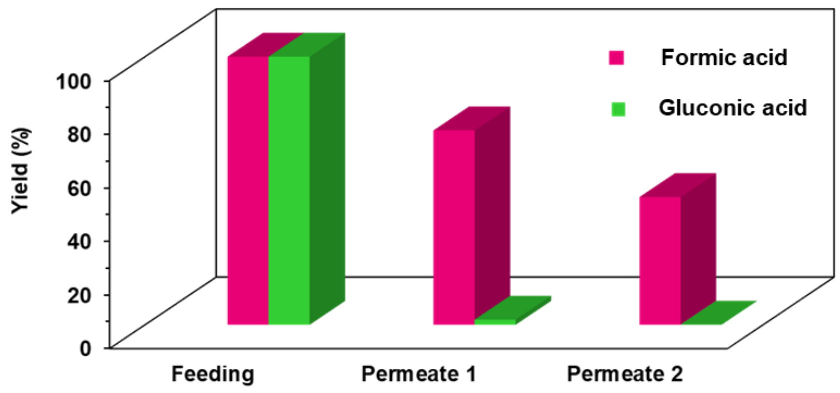
Nanofiltration

Permeate pathway							
Fraction	[F]	[G]	Y(F)	Y(G)	EF(F)	SF(F)	Purity (F)
Feed	1.80	9.00	100%	100%	1	1	16.7%
Permeate 1	1.87	0.24	72.5%	1.89%	38.4	112	88.5%
Permeate 2	1.37	0.006	47.6%	0.03%	1202	3515	99.6%

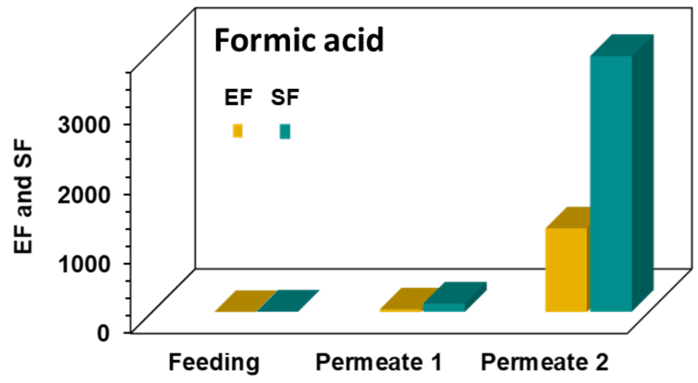
Concentrations of F and G



Yields of F and G



Enrichment (EF) and Separation (SF) Factors



$EF(F_p)=([F]_p/[G]_p)/([F]_f/[G]_f)$

$SF(F_p)=([F]_p/[G]_p)/([F]_r/[G]_r)$

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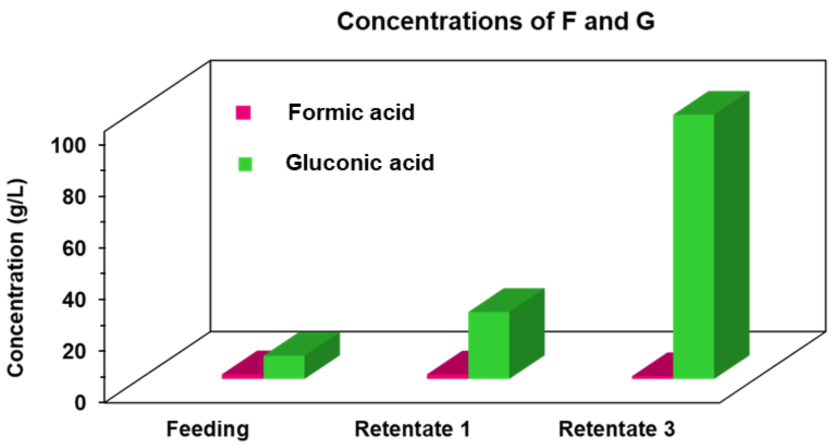
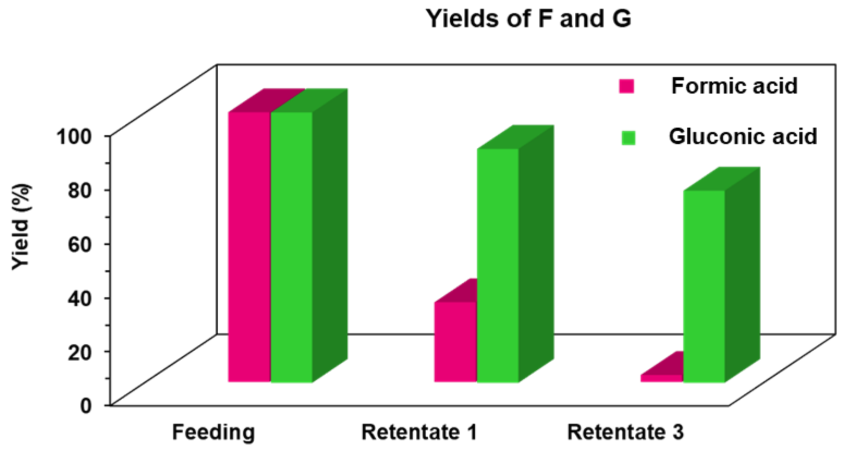
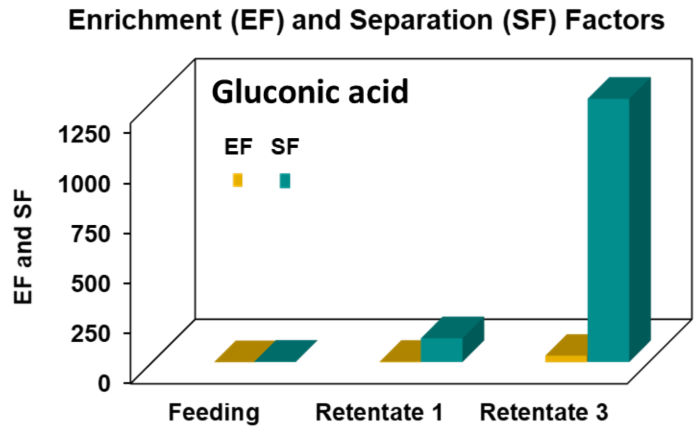
Step 1:

Nanofiltration

Retentate pathway							
Fraction	**[F]**	**[G]**	**Y(F)**	**Y(G)**	**EF(G)**	**SF(G)**	**Purity (G)**
Feed	1.80	9.00	100%	100%	1	1	83.3%
Retentate 1	1.78	26.0	29.6%	86.5%	2.95	113	93.6%
Retentate 3	0.63	102	2.38%	77.2%	32.7	1257	99.4%







$EF(F_p)=([F]_p/[G]_p)/([F]_f/[G]_f)$

$SF(F_p)=([F]_p/[G]_p)/([F]_r/[G]_r)$

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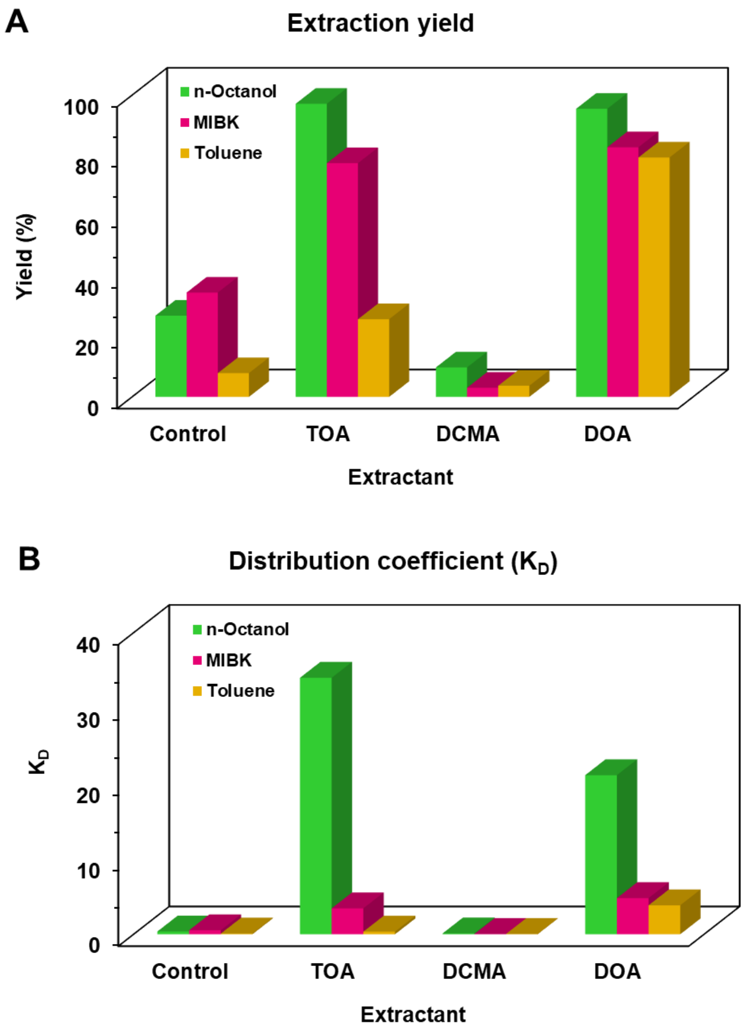
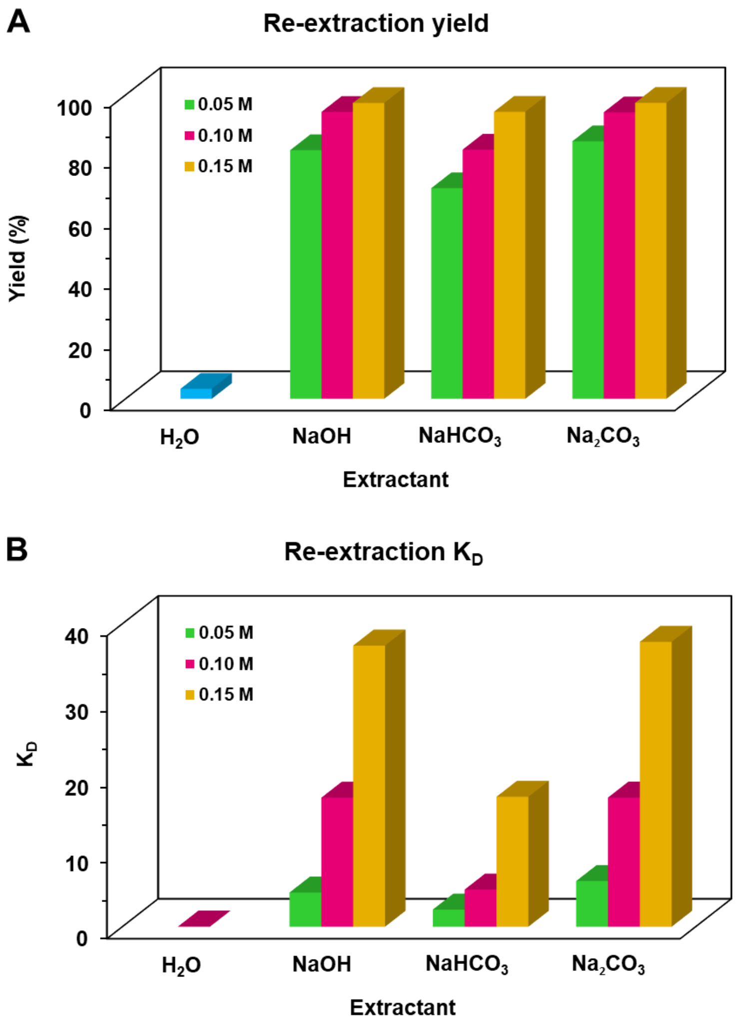
Step 2:

Reactive extraction



Extraction

Re-extraction



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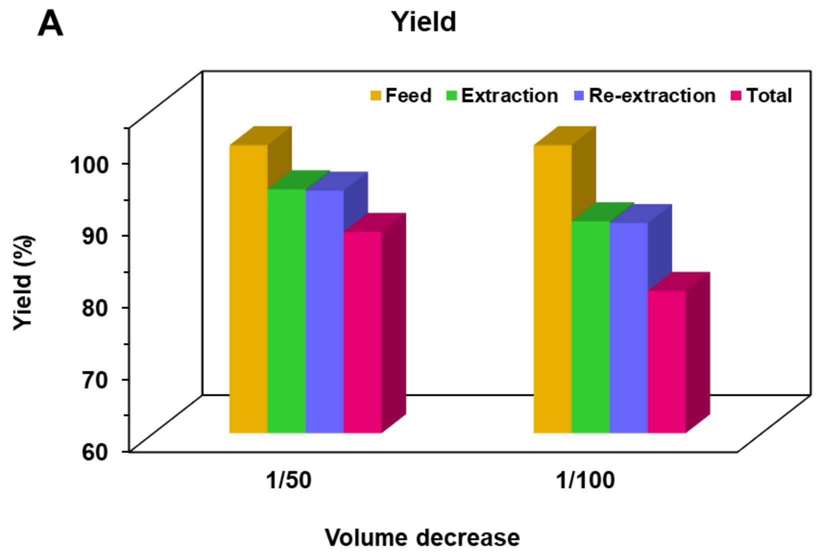
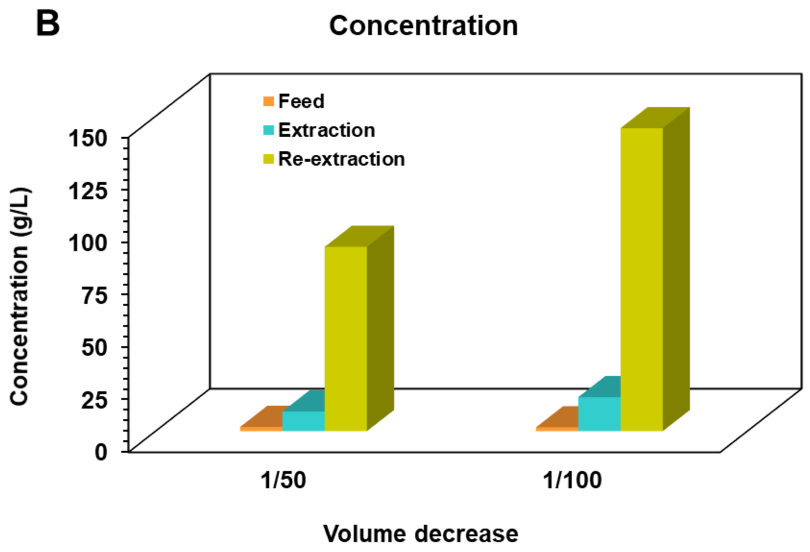
Step 2:

Reactive extraction





FEED		EXTRACTION		RE-EXTRACTION		WHOLE PROCESS			
pH = 2.7 V = 1000 mL		TOA 877 mM (n-oct) TOA/FA (mol) = 18.3 V = 100 mL (twice)		NaOH 6 M NaOH/FA (mol) = 14 V = 10 mL (twice)		V decrease from 1000 to 10 mL			
[FA] (g/L)	Y (%)	[FA] (g/L)	Y (%)	[FA] (g/L)	Y (%)	[FA] (g/L)	Y (%)	C. factor	V. decrease
2.24	100	19.8	88.5	174.5	88.1	174.5	77.9	77.9	1/100

Thank you

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