A novel TOA-glycerol based extraction- re-extraction process for the separation of chemicals produced by acidogenic fermentation of biomass

Juray De Wilde[1],

Emilie Fockedey[1], Patrick A. Gerin[2]

Université catholique de Louvain, Belgium

juray.dewilde@uclouvain.be

(1) Materials and Process Engineering Department

(2) Unit of Bioengineering

Ethanol and volatile fatty acids can be produced by acidogenic fermentation

Fermentable Biomass

↓

Acidogenic fermentation

↓

Fermentation broth

- Water
- Ethanol
- Acids: Acetic, propionic, butyric and lactic

Concentrating ethanol and acids is necessary

- Acidogenic fermentation advantages:
  - Non-axenic conditions
  - Any fermentable biomass
  - Non-pretreated biomass
- Acidogenic fermentation limitations:

very diluted aqueous solutions (+/- 1% organic acids) produced

→ Separating and concentrating the molecules is essential

Development and optimisation of an efficient process for the separation of organic acids from the fermentation broth

Fermentation broth

↓

SEPARATION

↓

Acetic, propionic, butyric, lactic acids
Ethanol

Outline

- Separation process
- Experimental study
- Modeling
- Conclusions and perspectives

Liquid-liquid extraction seems to be the most promising technique

- Technique for the lactic acid : precipitation

  Expensive and non environment-friendly

- Other separation techniques
  - Distillation

    Large water flow to evaporate
  - Vapor permeation

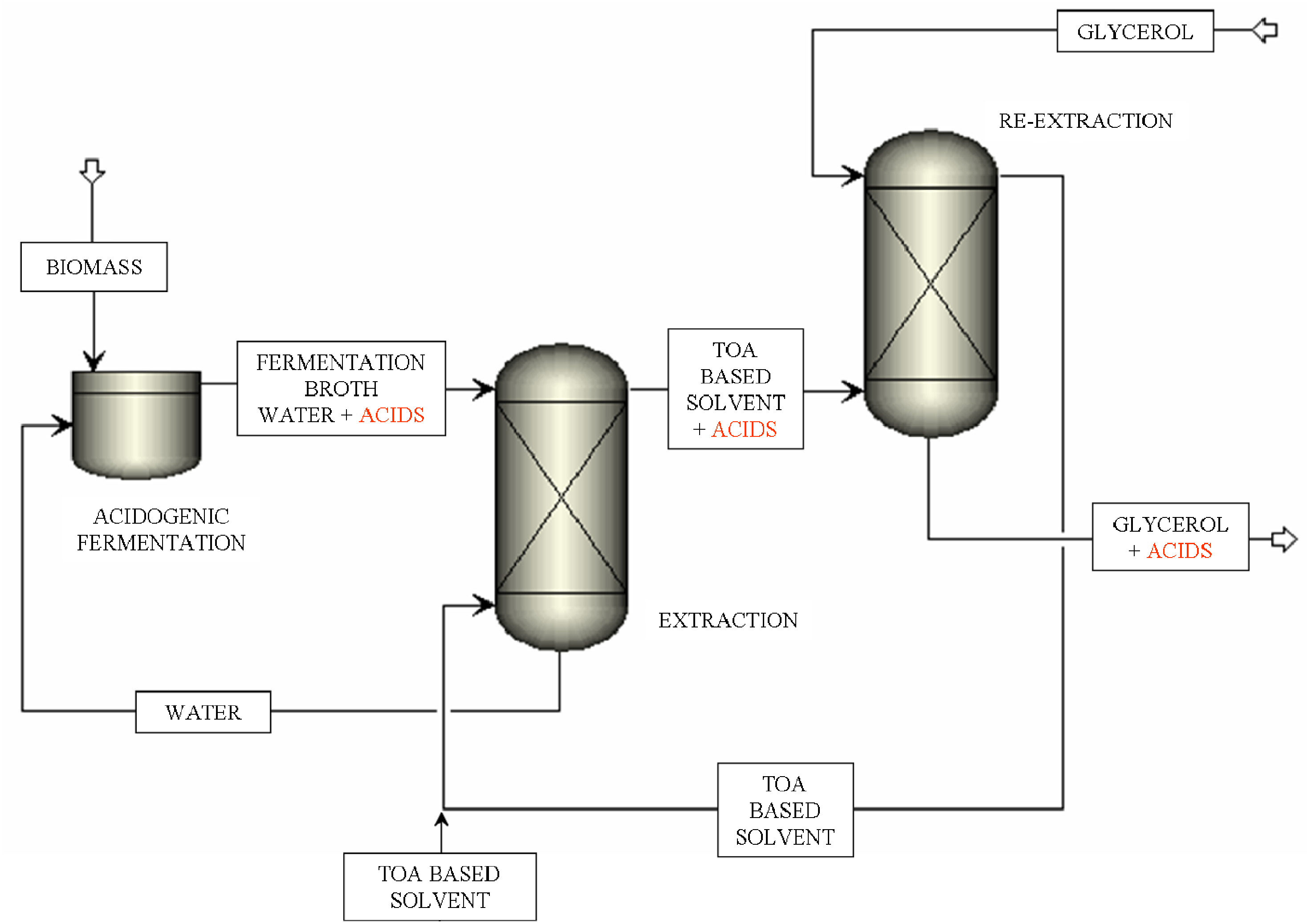
    Large water flow to evaporate
  - Pervaporation

    Large water flow to evaporate

    No available membrane
  - Electrodialysis

    Unefficient use of electric energy
  - Extraction **PROMISING OPTION**

Complete process based on two liquid-liquid extraction columns



Outline

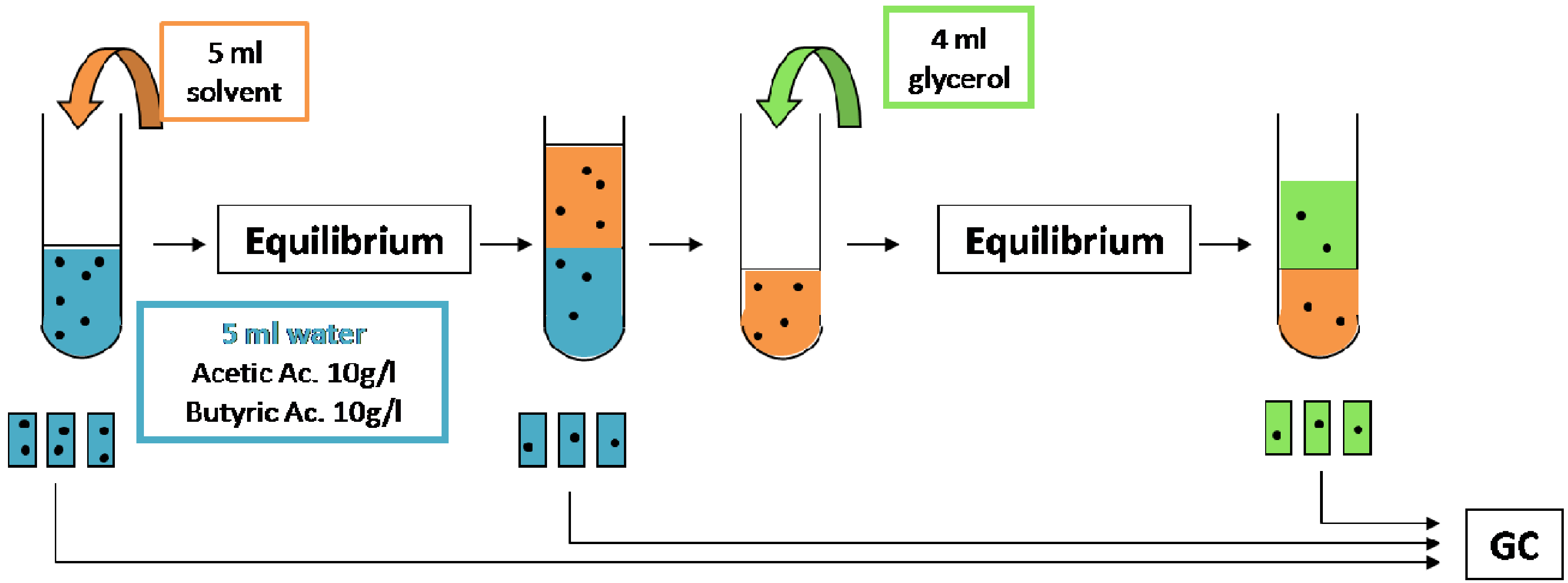
- Separation process
- Experimental study
- Modeling
- Conclusions and perspectives

Distribution coefficients

Distribution coefficient:

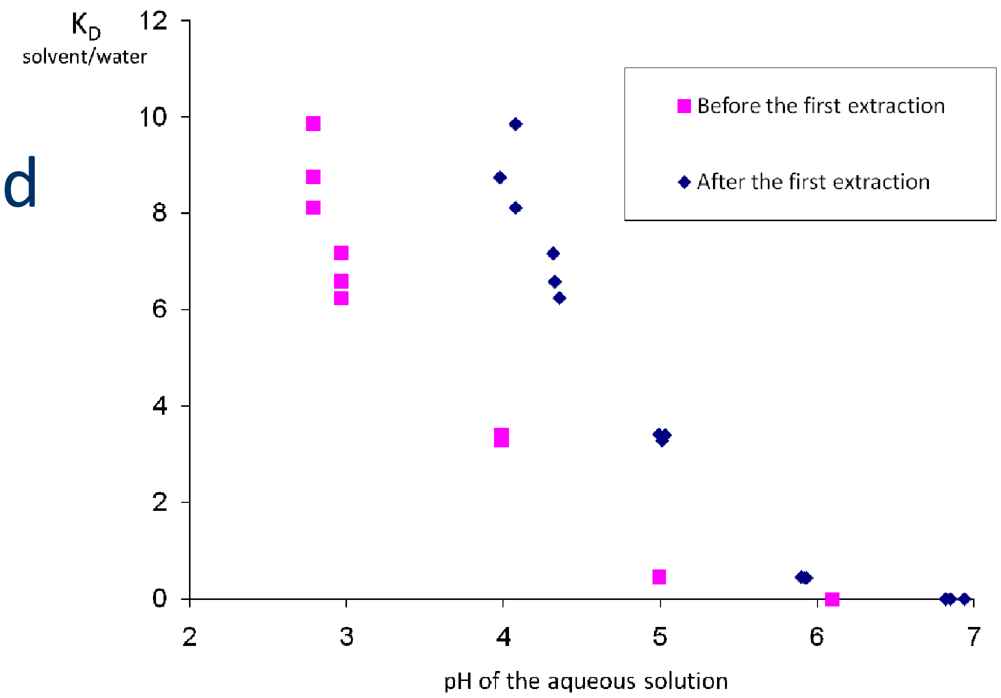
$$K_D = \frac{x_A^{extract}}{x_A^{raffinate}}$$

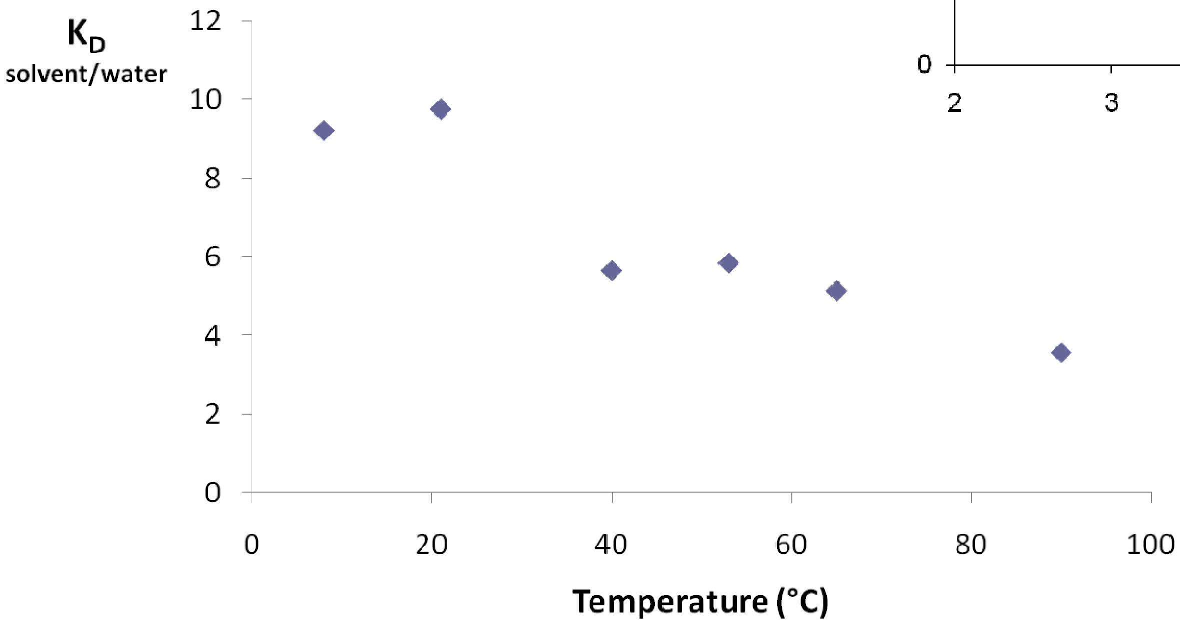
Experimental approach



Operating parameters strongly influence the distribution coefficient

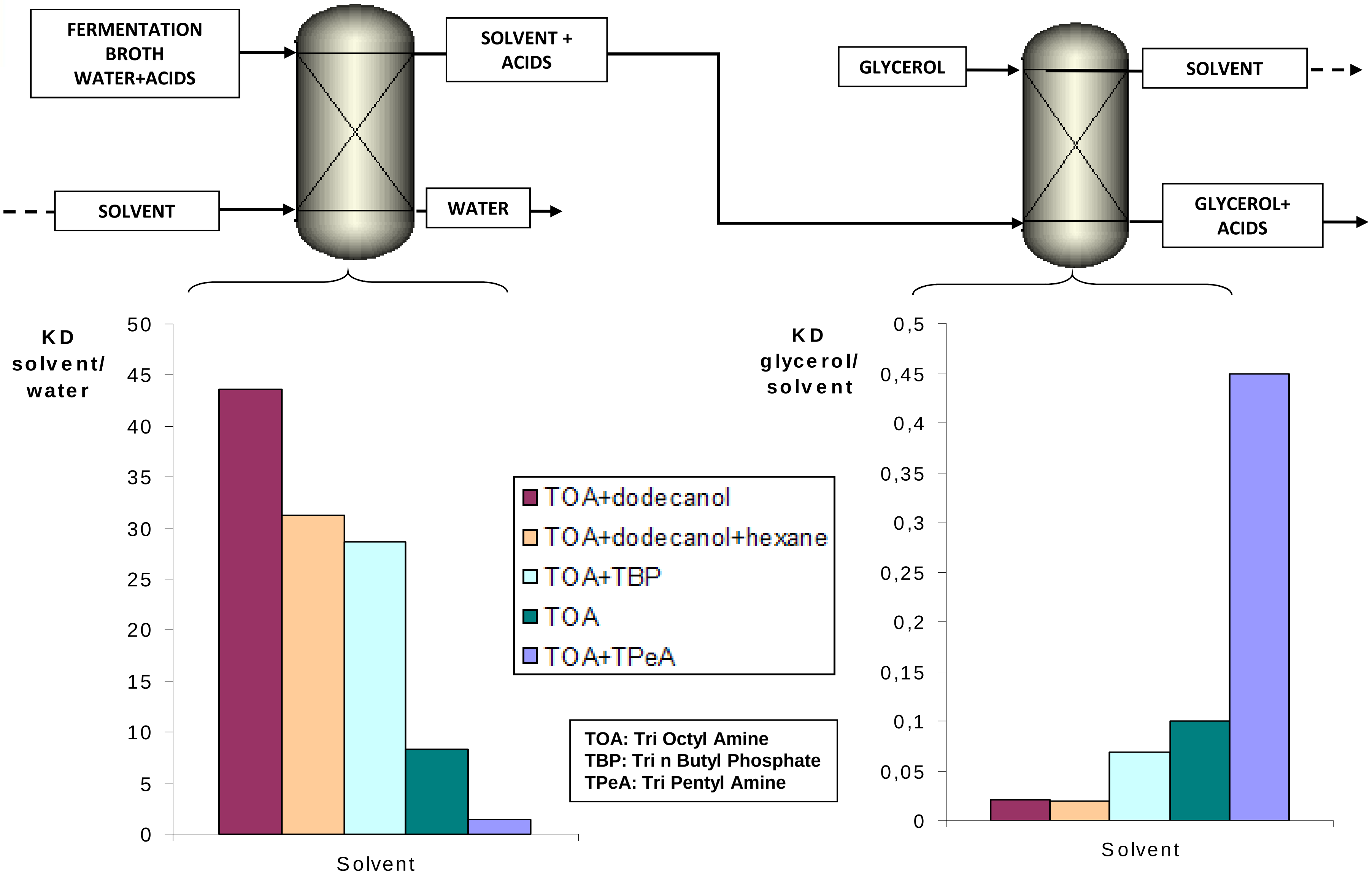
- Type of carboxylic acid
- pH
- Temperature





Used solvent :
Pure tri-n-octylamine (TOA)

Extraction efficiency is highly influenced by the composition of the solvent



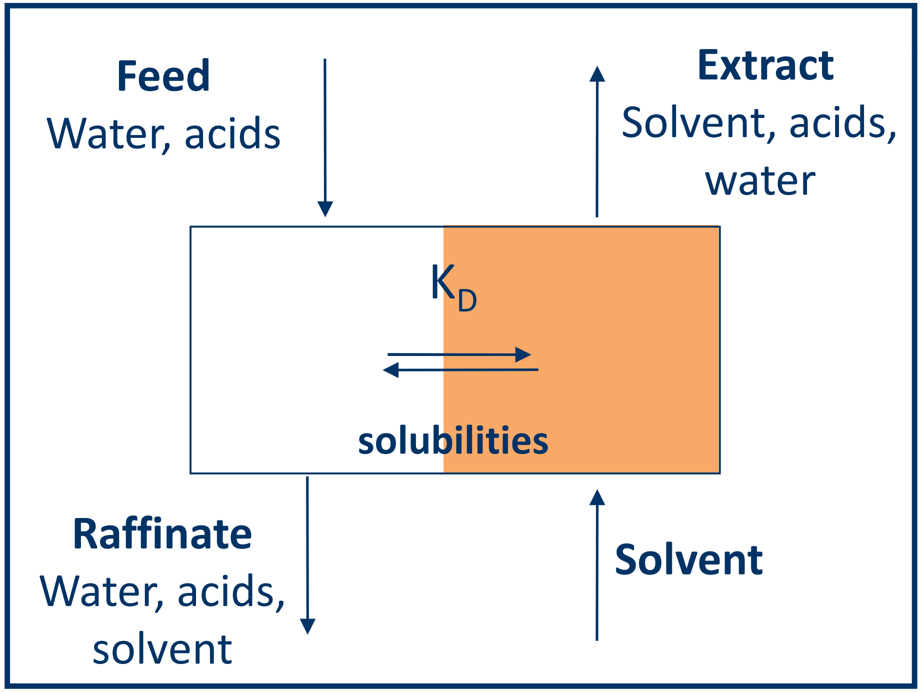
Outline

- Separation process
- Experimental study
- Modeling
- Conclusions and perspectives

Modeling

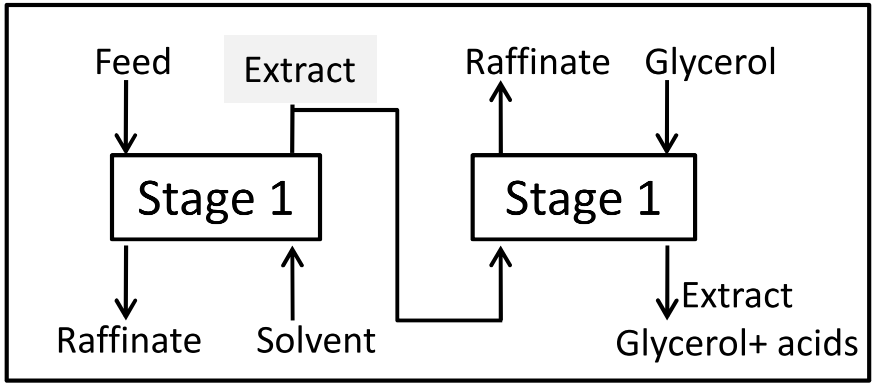
- Software simulating a countercurrent multistages liquid-liquid extraction column
  - Mass balances
  - Phase equilibria
    - K_D
    - Solubilities

- Data : experimental distribution coefficients and solubilities

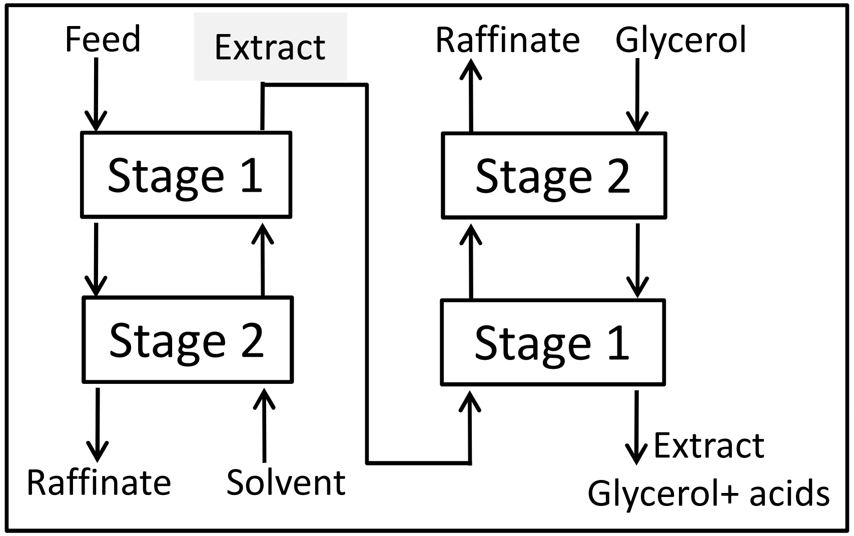


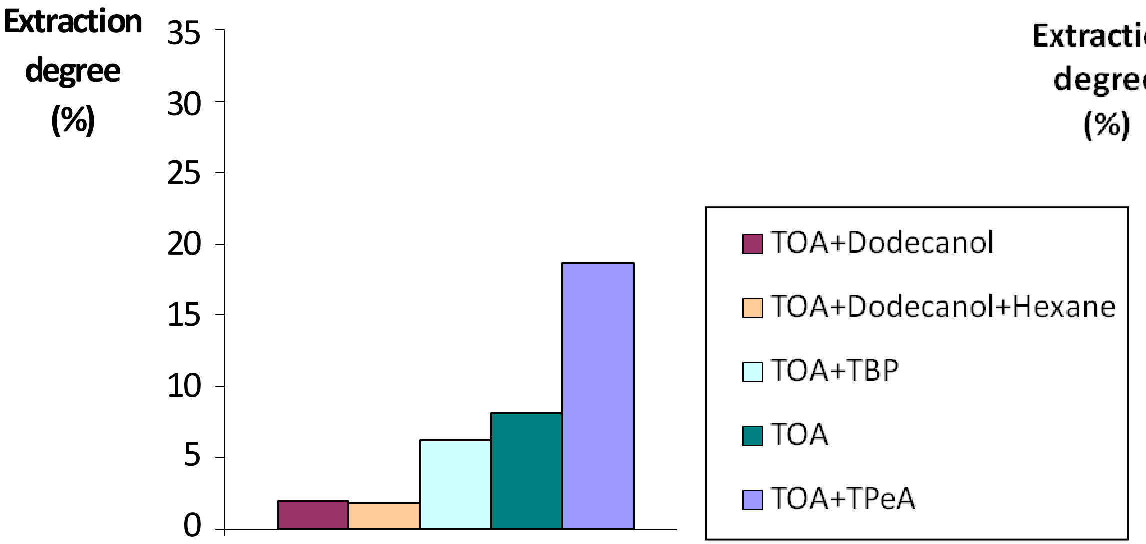
Simulations of the extraction-reextraction 2 steps process

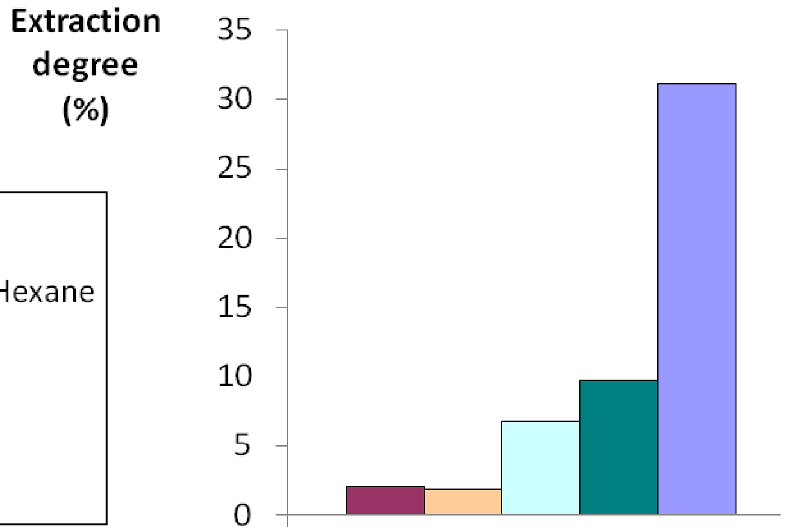
1 stage



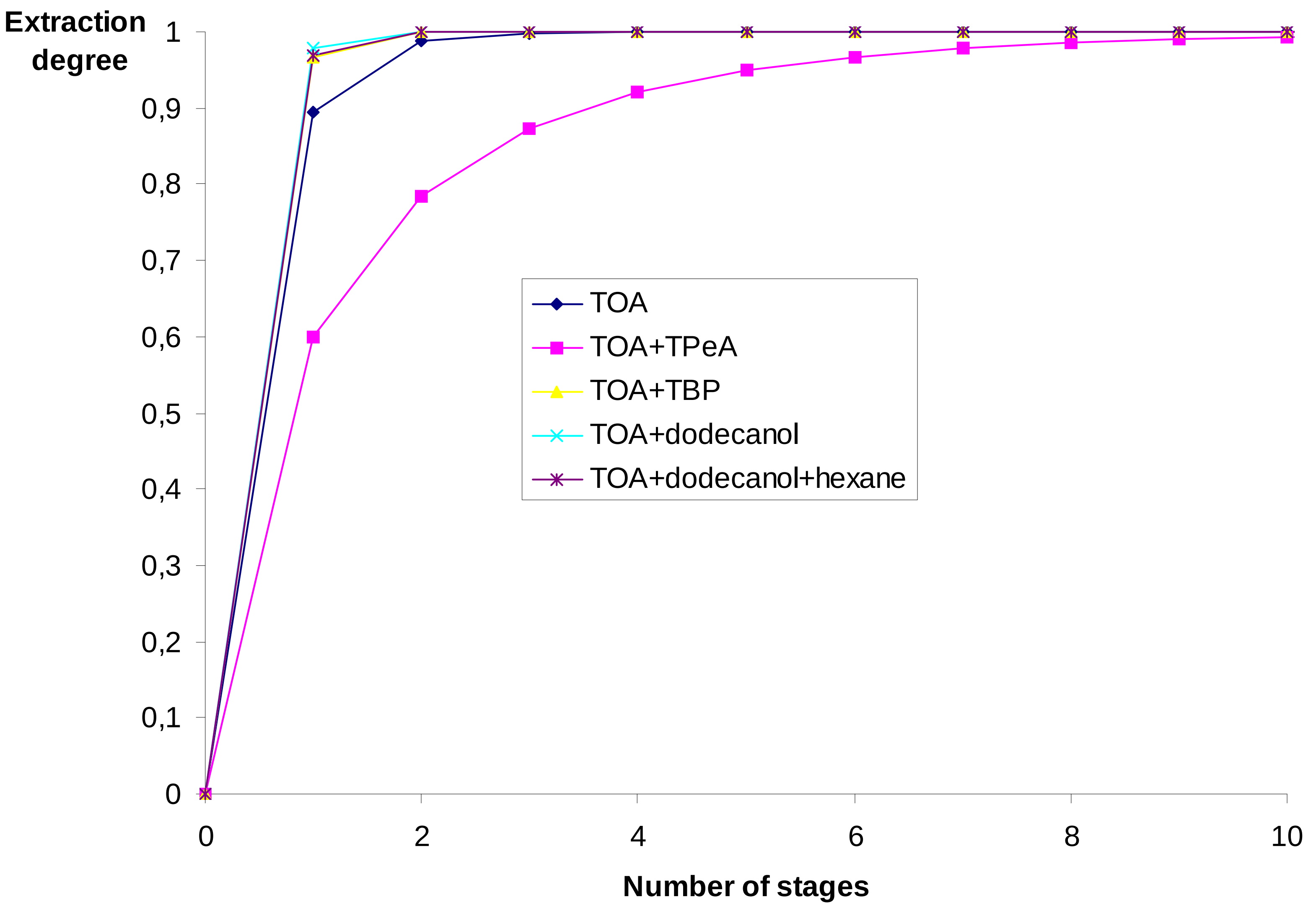
2 stages





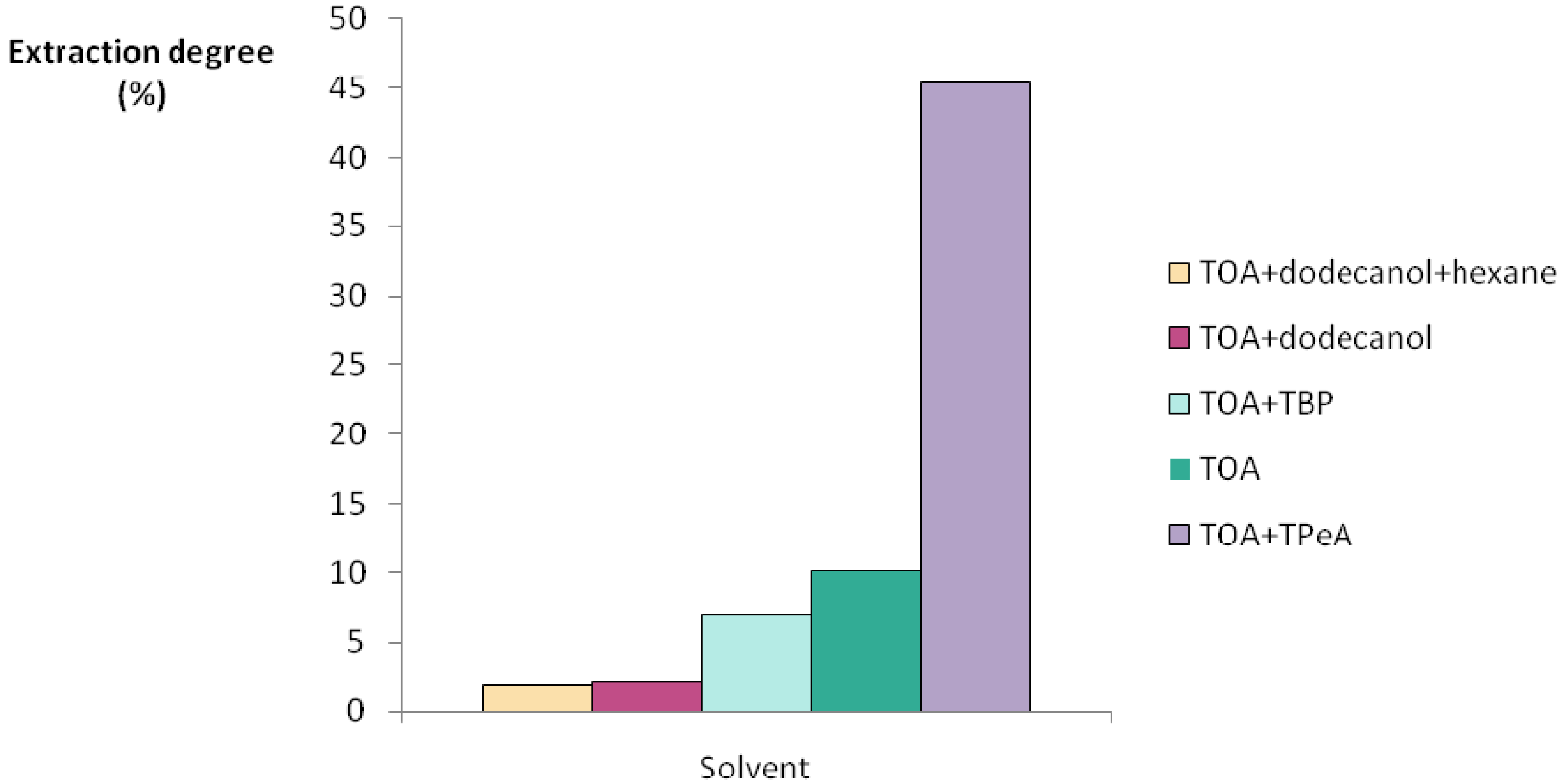


Extraction degree for the 1st extraction as a function of number of stages



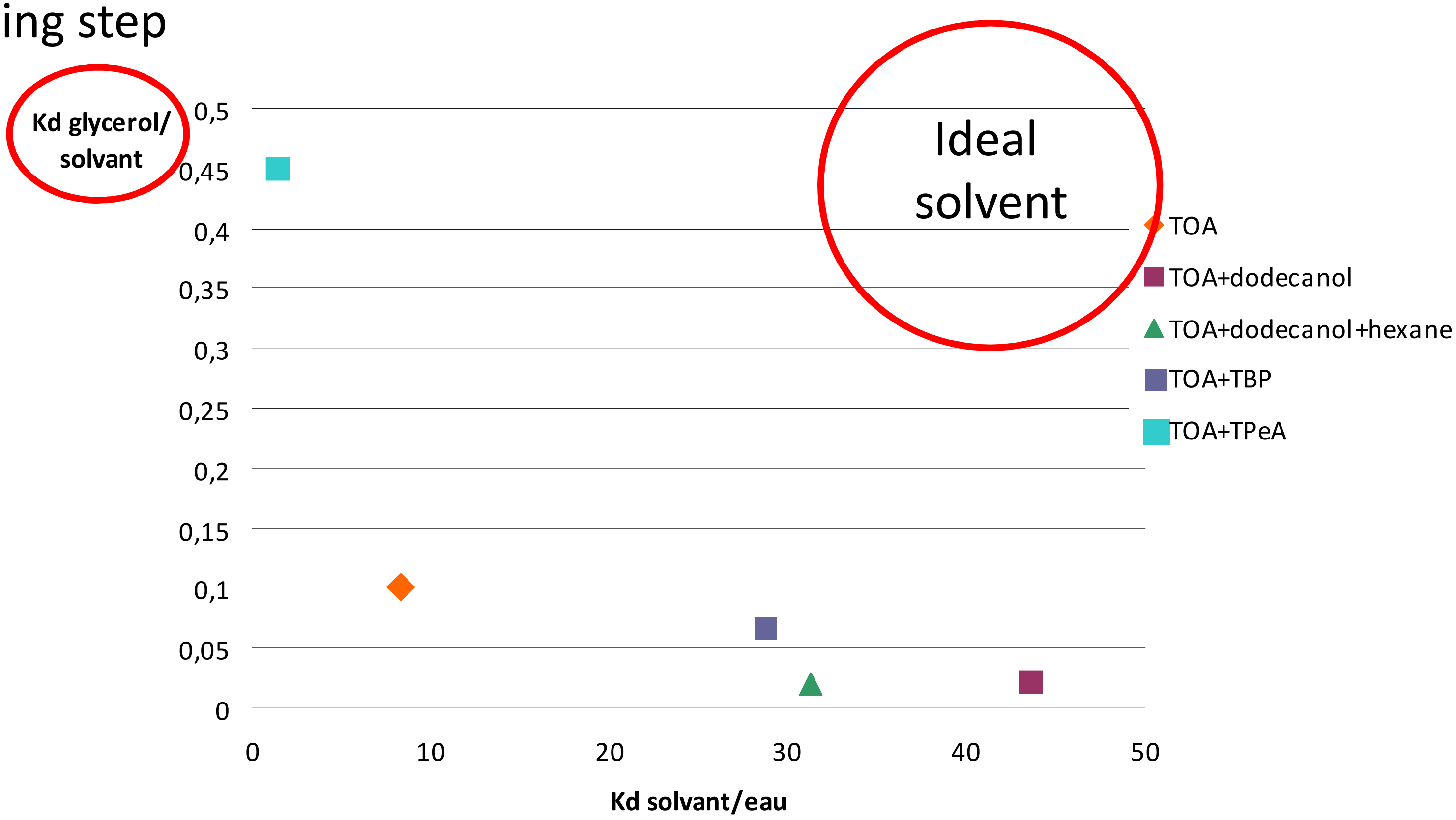
Extraction degree for the extraction – reextraction process

10 stages for each extraction column



$Kd_{glyc/solv}$ as a function of $Kd_{solv/water}$

Limiting step



Which solvents are less efficient for the first extraction?

Next step: extraction with vegetable oils

Table 2. Distribution Coefficients of Butyric Acid for Different Solvents Tested at $T = 298.15$ K[a]

solvent type	solvent	D	$C_{BA(aq)}$	literature
vegetable oil	haselnut oil	1.08	0.468	this study
	corn oil	1.08	0.462	this study
	soybean oil	1.08	0.469	this study
	olive oil	1.08	0.476	this study
	sunflower oil	0.99	0.523	ref 6
	rape seed oil	1.02	0.510	ref 6

[a] $C_{BA(aq)}$, butyric acid concentration at equilibrium in aqueous phase.

low distribution coefficients

Bilgin, et al. (2006) *Distribution of butyric acid between water and several solvents*, Journal of Chemical and Engineering Data, 51, pp 1546-1550

Conclusions and perspectives

- Operating conditions and solvents screening
- Fermentation broth
- Efficiency of the process at the industrial scale
- Verification on a pilot equipment