Influence of whey protein denaturation on adherence of soiling particles to stainless steel

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Presentation outline

1. Introduction

- Background
- Objectives

2. Experimental aspects

- Material
- Methods

3. Results and discussion

4. Conclusion

Concern ?

Particulate deposition on surface - drying

➔natural environments

➔industrial equipments

Where ?

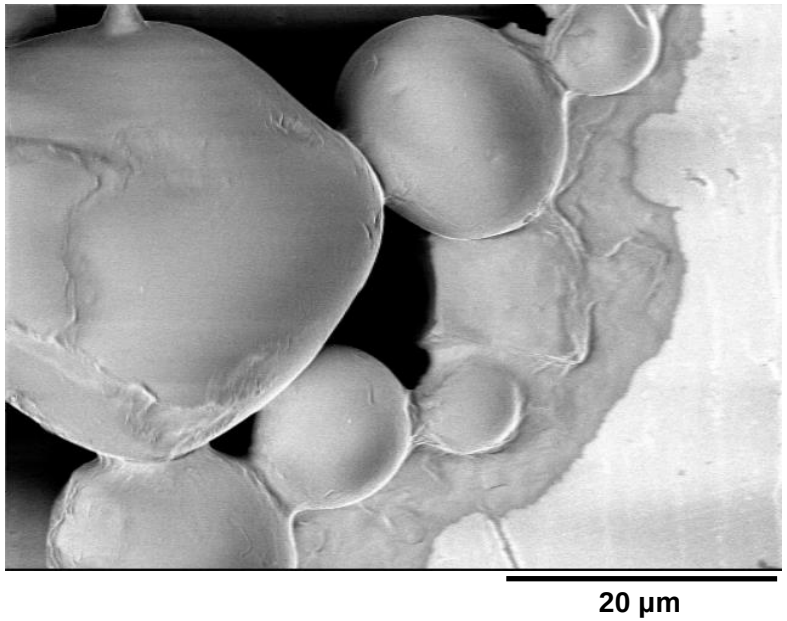
- **Storage tanks**
- **Ducts**
- **Plates of heaters coolers**

➔Food processing

Soil attachment and removal: influence of macromolecules at particule-substrate interface

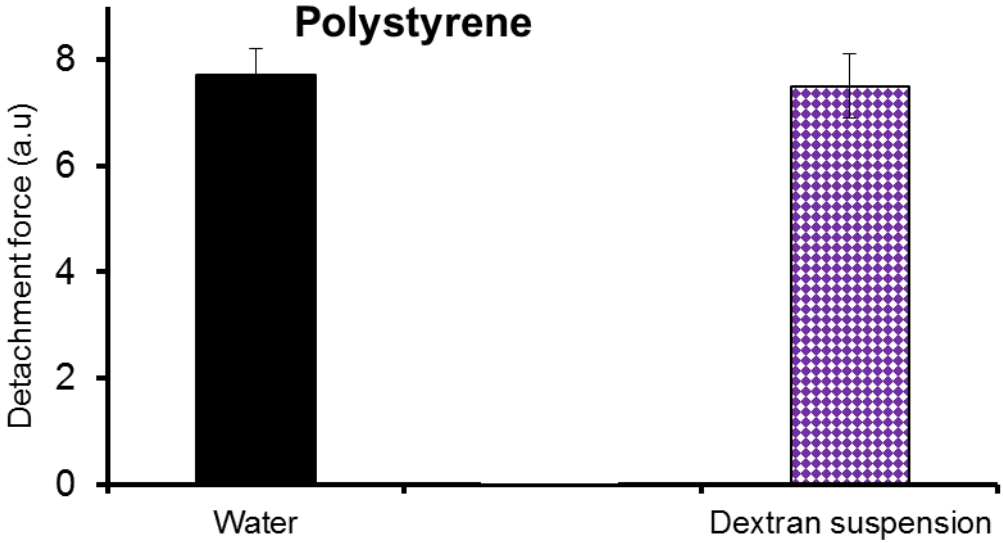
Detry et al. (2011): starch deposit

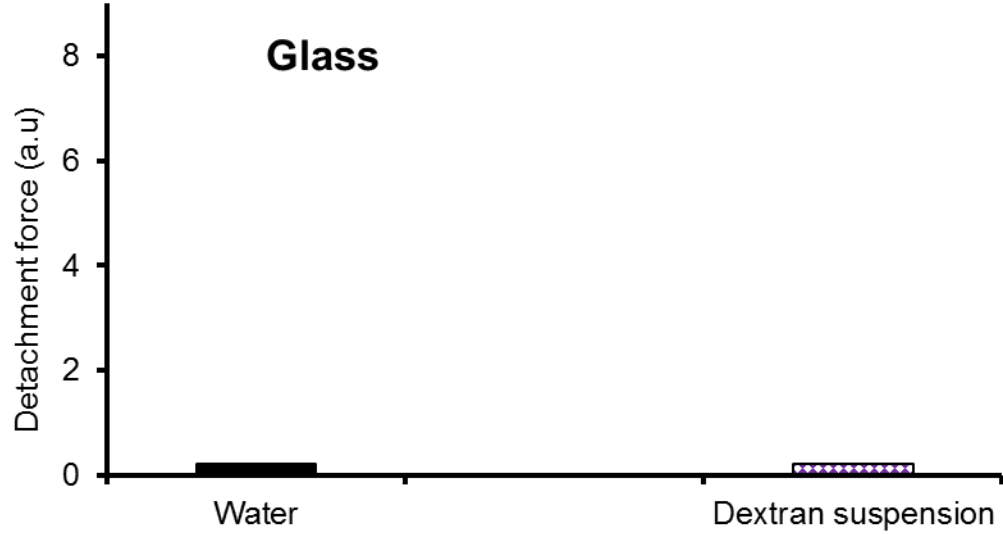
- **presence of macromolecules (polysaccarides, proteins)**
- **accumulation at substrate-particulate interface**
- **influence of:**
  - **details in the mode of drying**
  - **exposure to moisture**



Touré et al et al. (2011; 2013): quartz particles deposit

- **dextran, weak effect, low adsorption easy desorption**

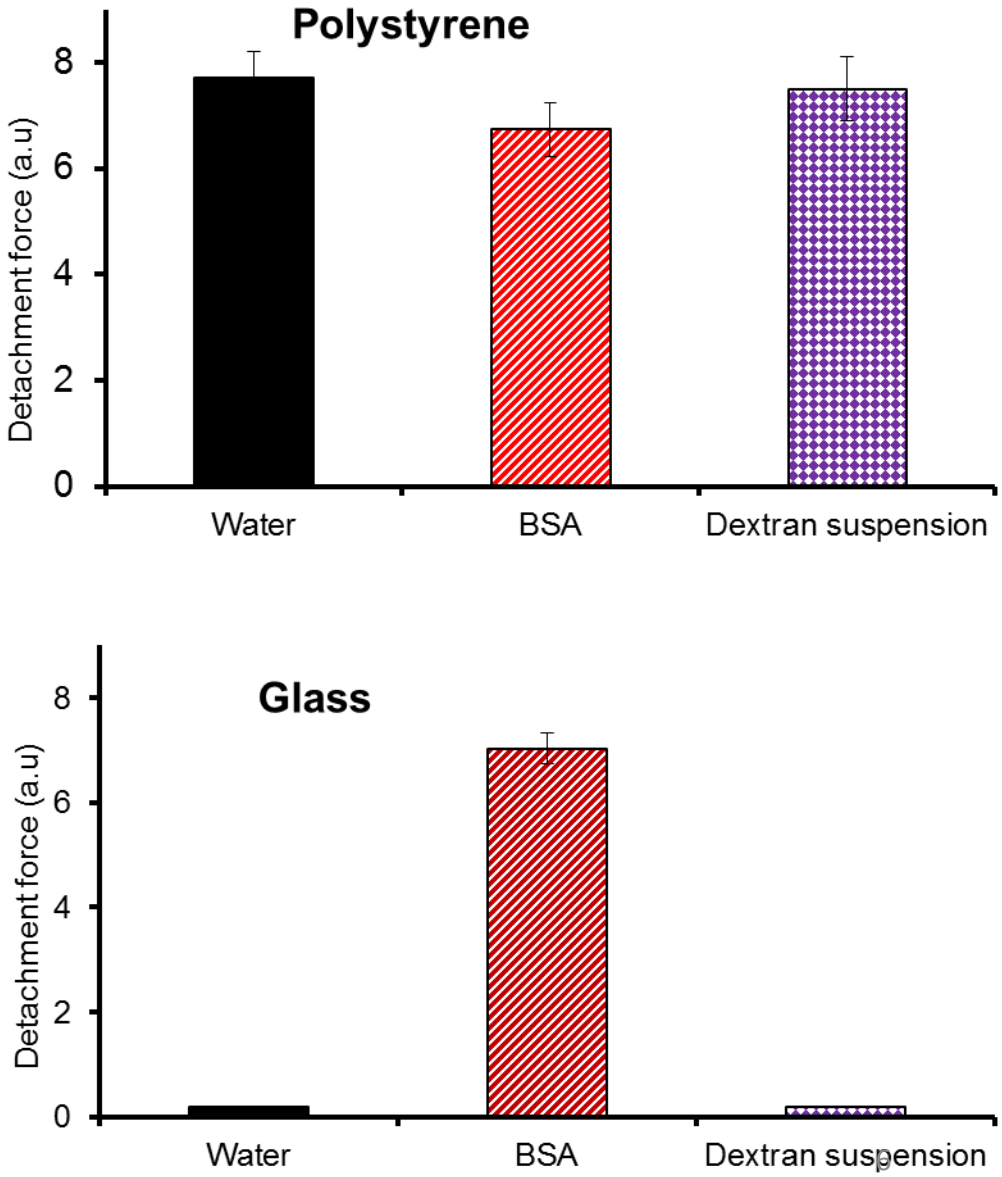




Background

Touré et al et al. (2011; 2013): quartz particles deposit

- **BSA:**
  - **on polystyrene: negligible effect**
  - **on glass: drastic ↗ cleanability**
    prevention of tight bonds
    induction of a repulsion



Protein used in food industry improves

fabricated foods qualities

- texture

- appearance

Denaturation of whey protein and fouling:

- **deposit build-up and removal**
  controversial question
- **particle soil adherence**
  no data available

Understanding the influence of protein denaturation on particulate soils adherence and removal

- **practical information on**
  - **incidence of surface properties of soil and substrate**
  - **influence of biomacromolecules**

- **physico-chemical mechanisms involved :**
  - **interactions solid-solution, solid-solid**
  - **biomacrolecules at interfaces**

- **designing easy-to-clean surfaces**

Understanding the influence of protein denaturation on particulate soils adherence and removal

This work:

to improve

- **evaluating cleanability**
- **understanding mechanisms involved**

Material

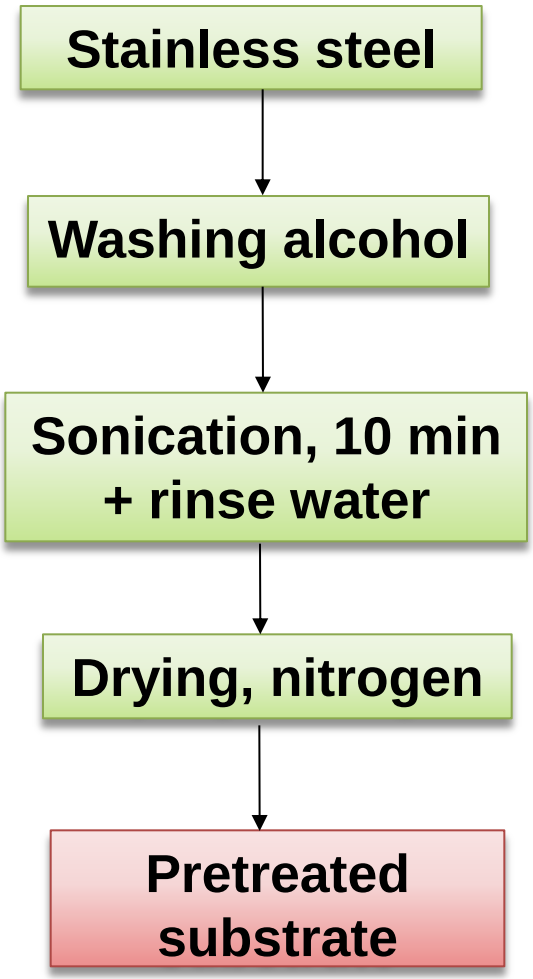
Model of whey protein : **β-lactoglobulin (β-LGB)**

Model of substrate : **stainless steel**

Model of particulate soil : **suspension of quartz particles (10-30 µm)**

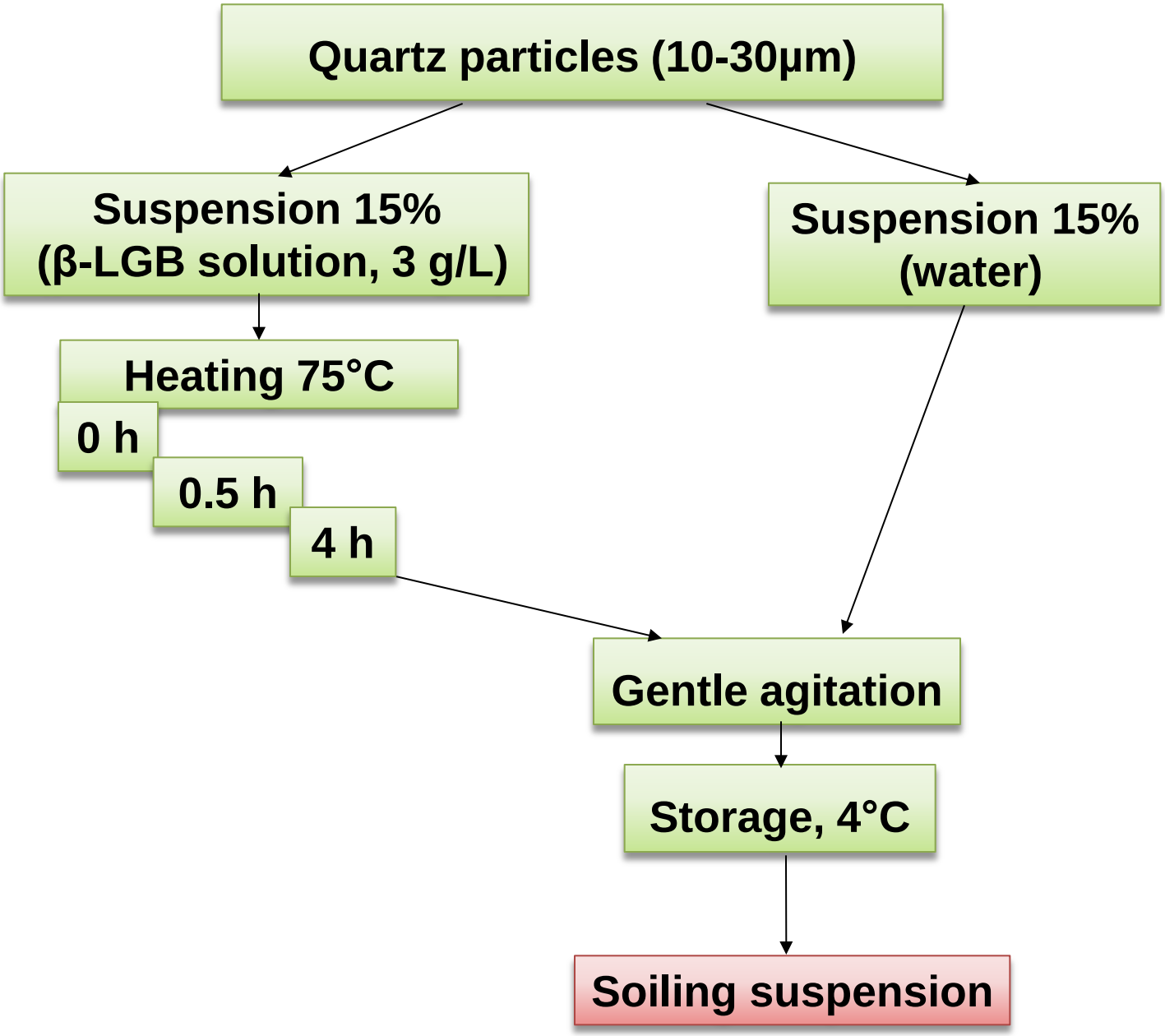
2. Experimental aspects

Substrate pretreatment



2. Experimental aspects

Soil preparation



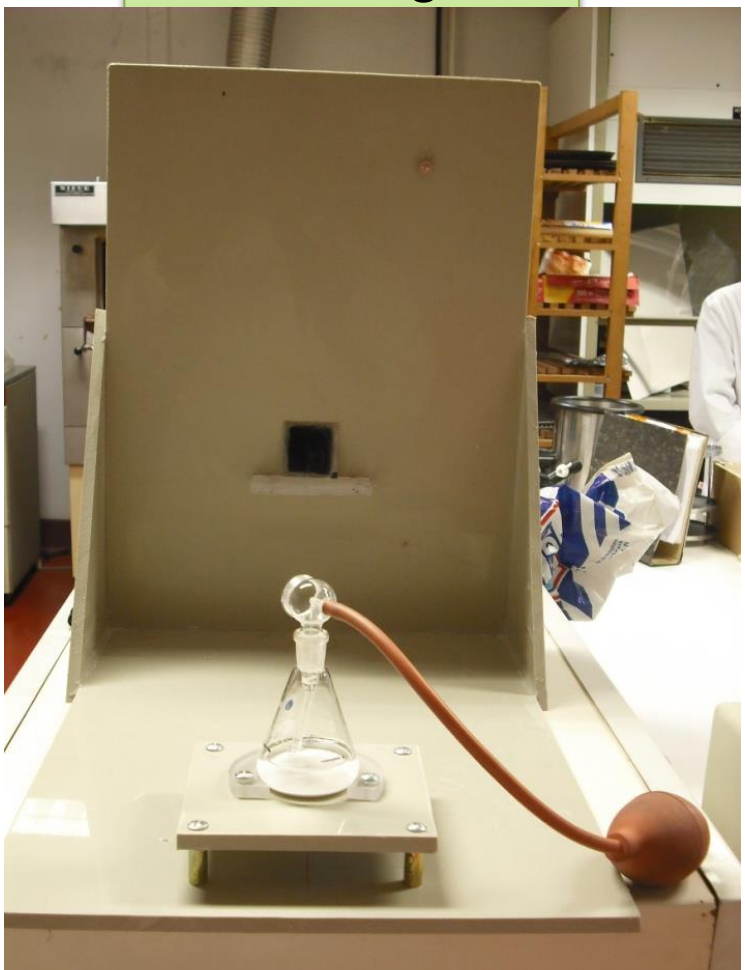
2. Experimental aspects

Soiling procedure

Pretreated substrate

Soiling suspension

Soiling



2. Experimental aspects

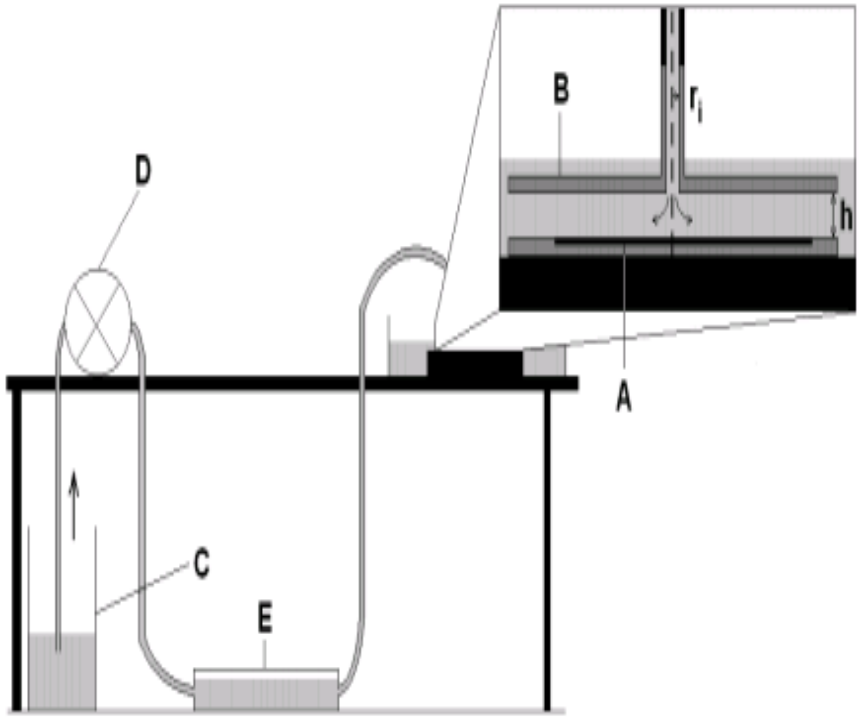
Cleaning test

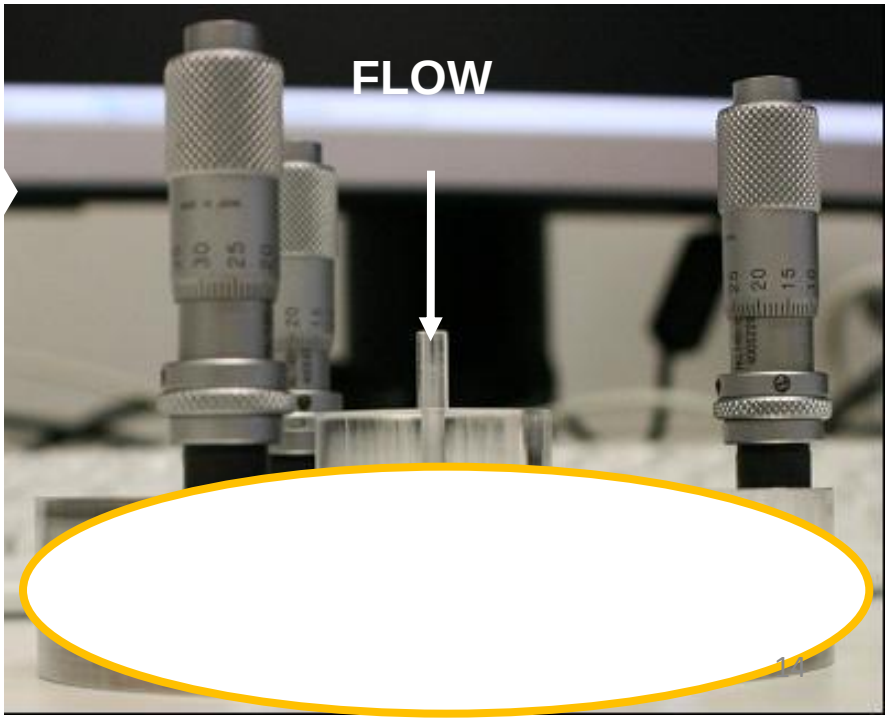
Drying, 30 min,
19 ± 5°C, 39% H

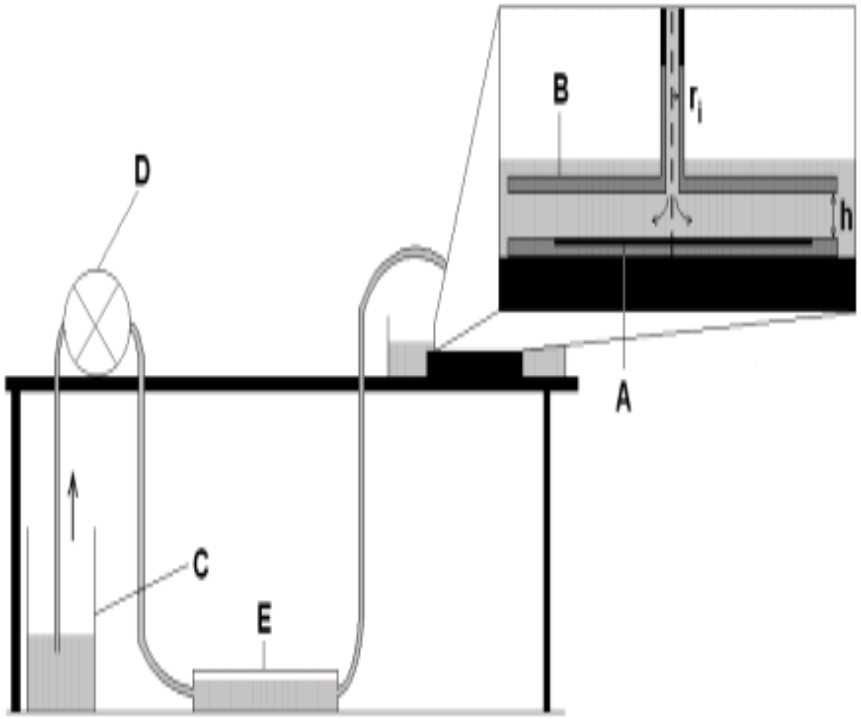
Drying, 30 min,
75 ± 5°C

Picture I

Radial-flow cell
(40 ml/min)



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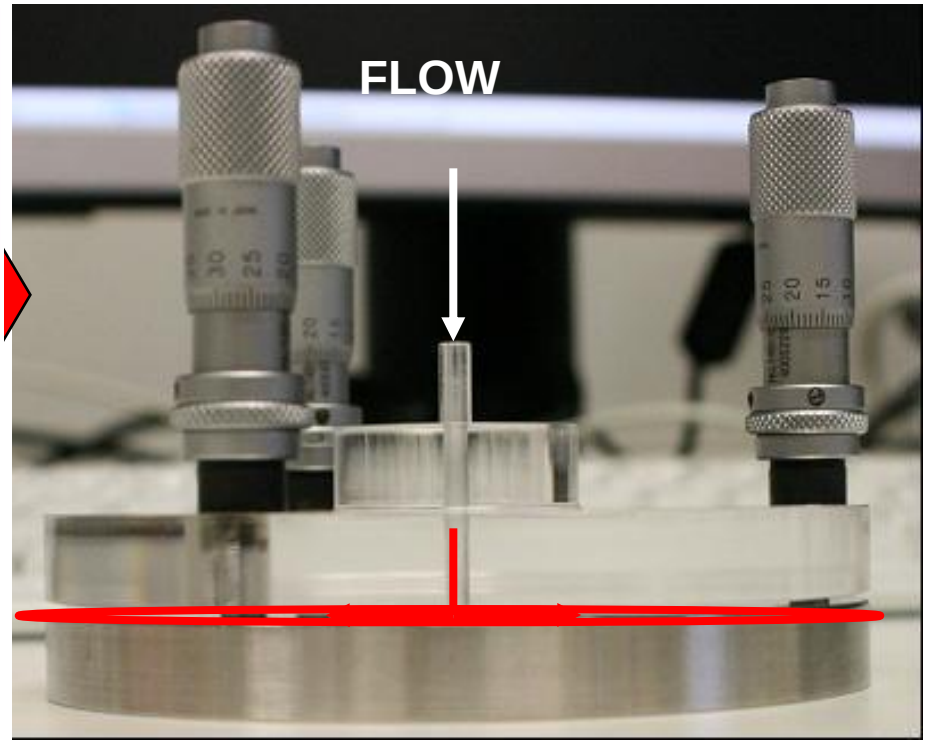
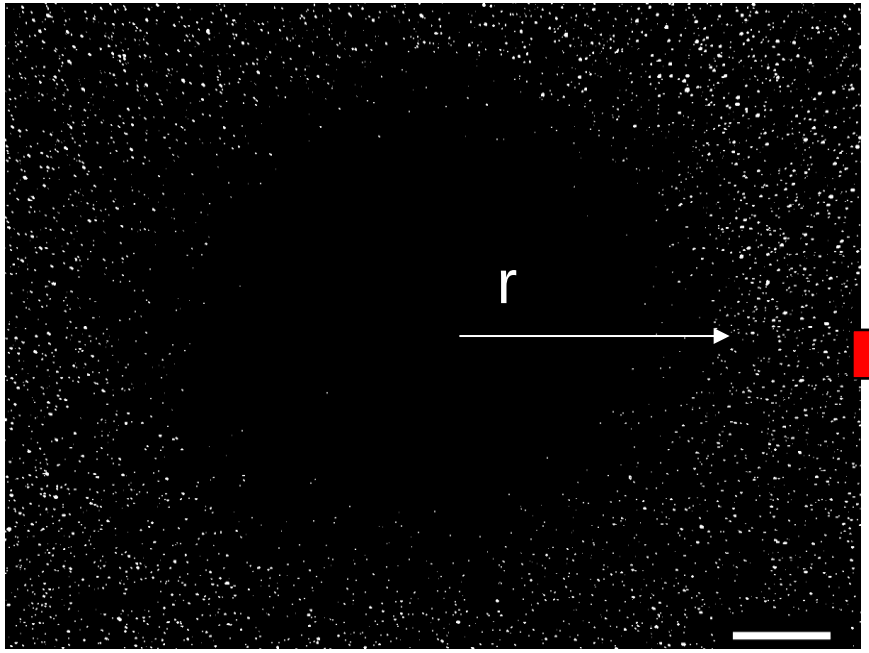

FLOW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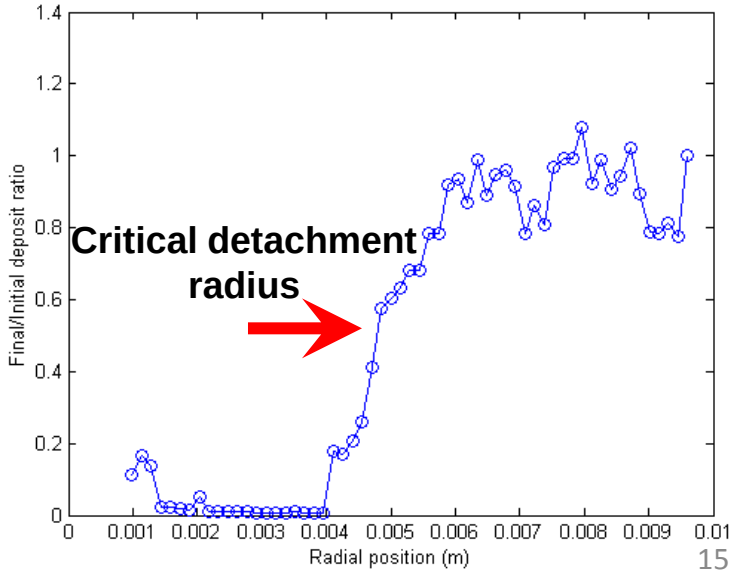
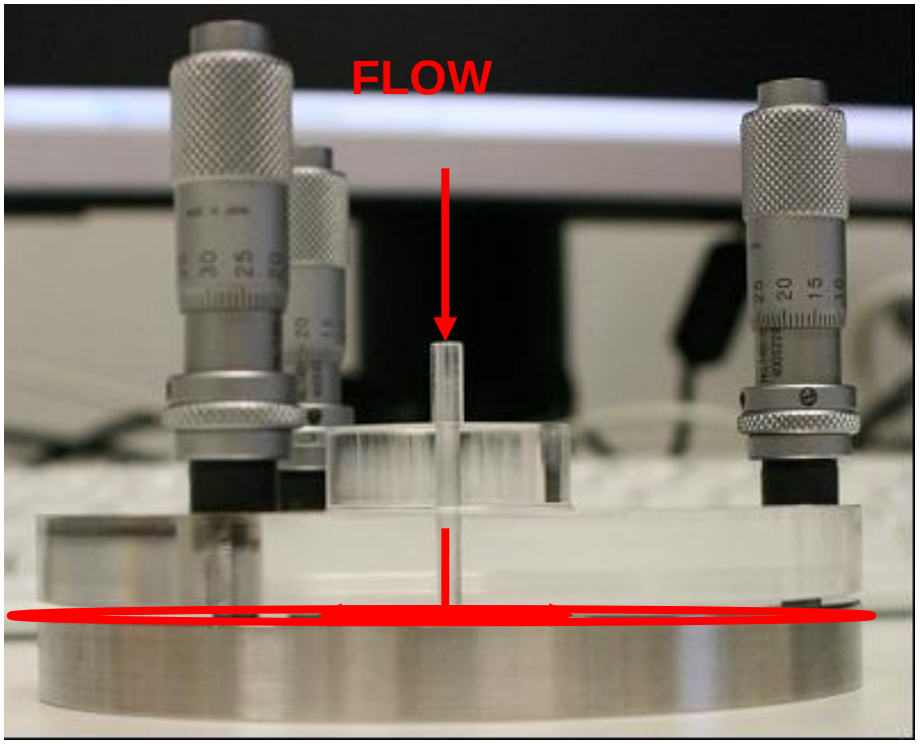
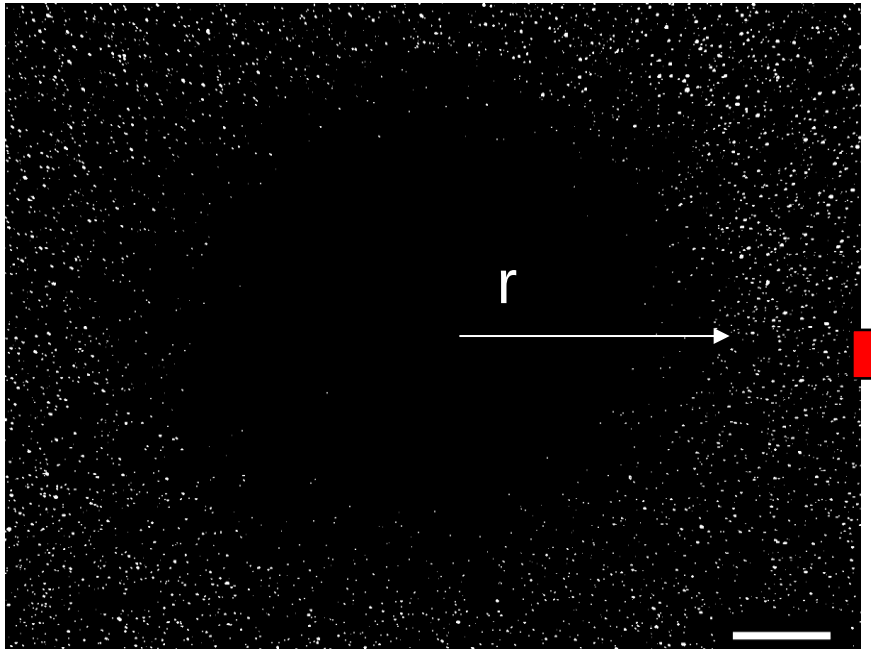
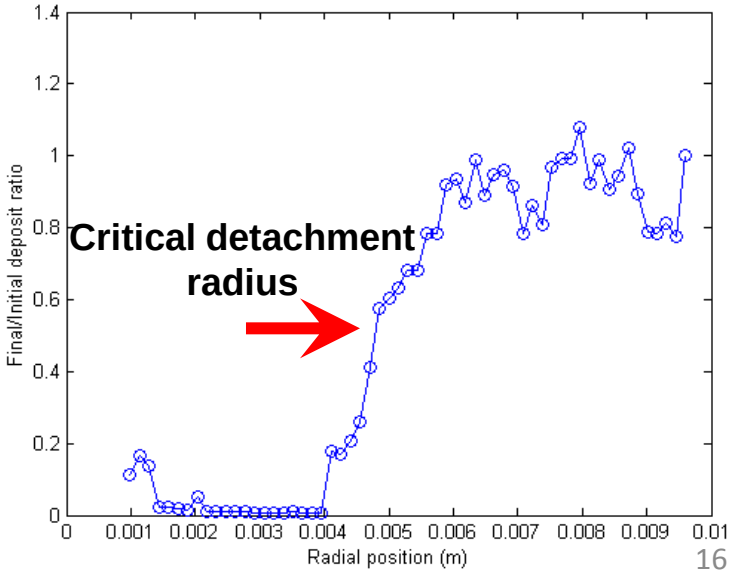

Critical detachment radius
Final/Initial deposit ratio
Radial position (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.01

- **At given flow rate:**
  larger critical detachment radius
  ↔ lower hydrodynamic drag force
  required to detach particles

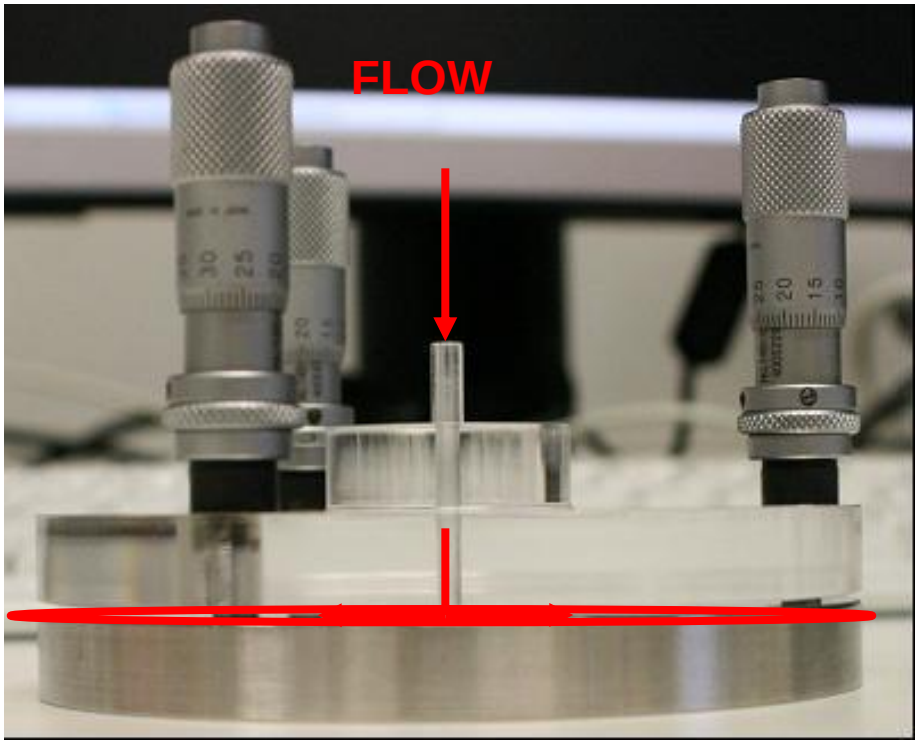


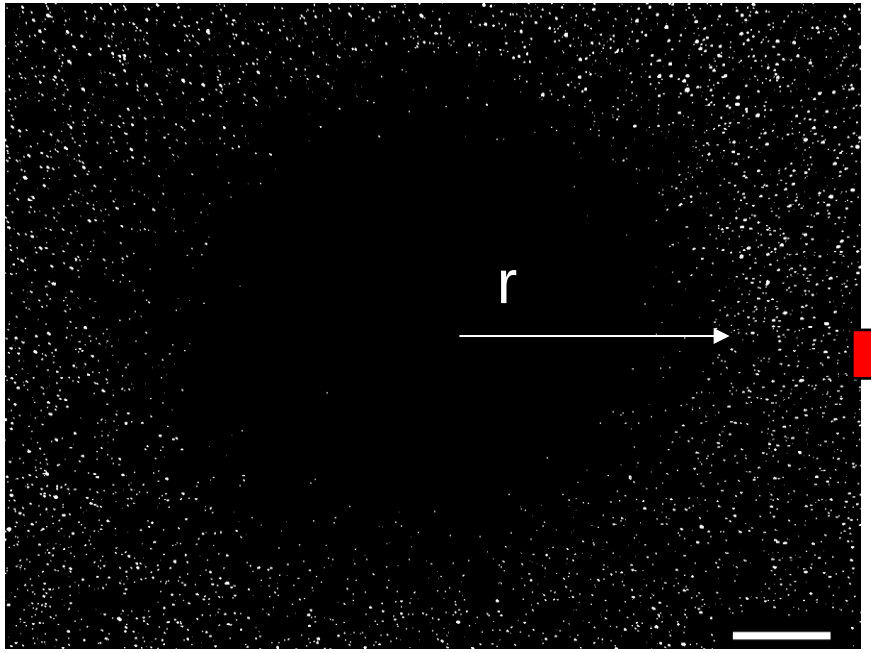


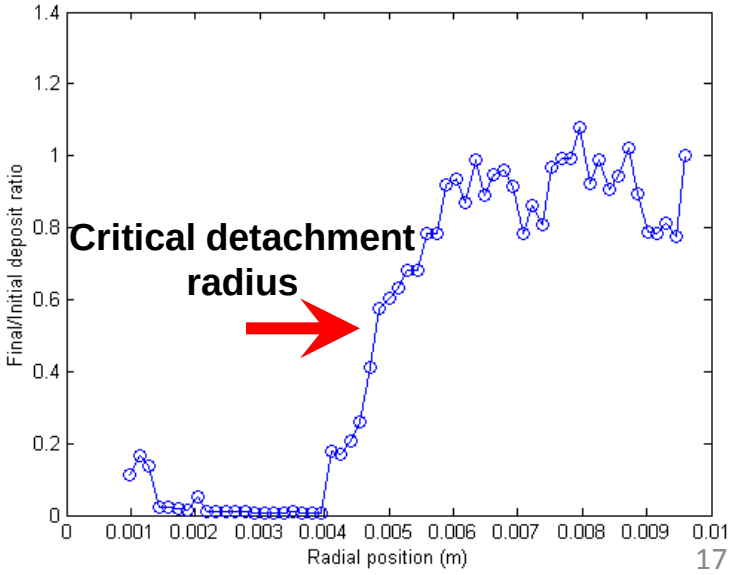


- **At given flow rate:**
  larger critical detachment radius
  ↔ lower hydrodynamic drag force
  required to detach particles

- **Increasing the flow rate**
  same critical detachment radius
  ↔ increasing drag force
  required to detach particles







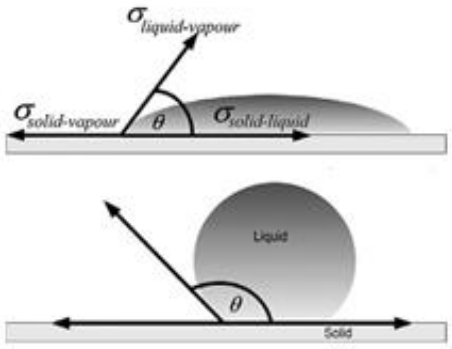
Characterization

Solution and supernatants

- UV-visible absorption
- soluble protein concentration
- liquid surface tension

Substrate

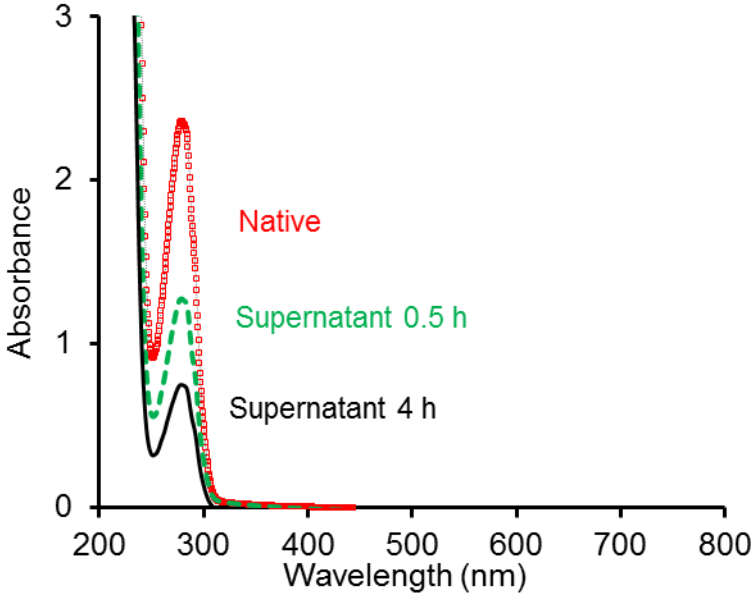
- static contact angle
  - water
  - supernatants

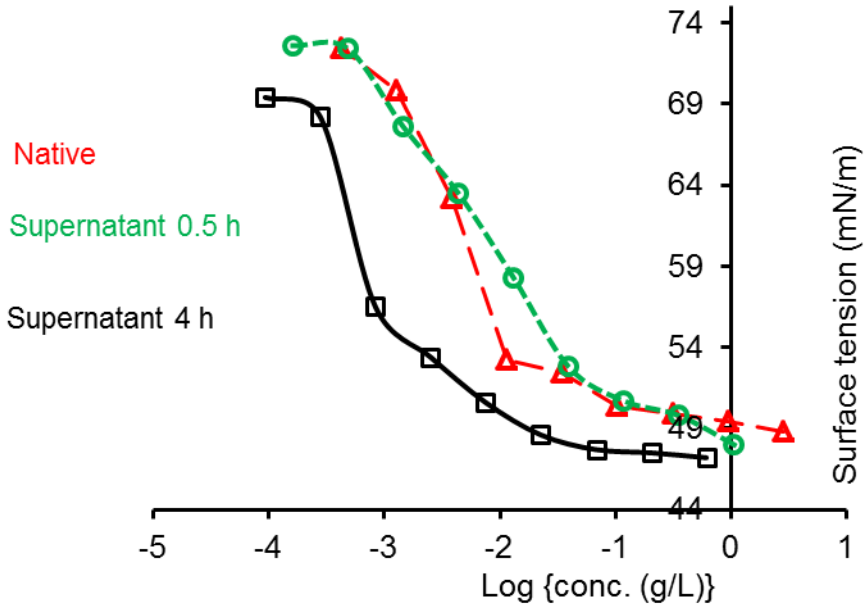


- XPS analysis
  - bare substrate
  - conditioned substrates

3. Results & discussion

Solution and supernatants





	Native	Supernatant 0.5 h	Supernatant 4 h
Concentration (g/L)	2.5 ± 0.2	1.1 ± 0.2	0.6 ± 0.1

Heating β-LGB solution at 75°C

- 0.5 h ➔ aggregation 50%
- 4 h ➔ aggregation 75%,
  lower surface tension
  ➔ higher activity at water/air interface

3. Results & discussion

Surface chemical composition

Conditioning liquid	Heating	Rinsing	Proportion (%) of elements due to adlayer	Proportion (%) of elements due to substrate	Molar ratios in organic adlayer O_{org}/C_{tot}	Molar ratios in organic adlayer N/C_{tot}	Molar ratios in organic adlayer O_{org}/N
none	none						
	4 h						
β-LGB	none	none					
		twice					
	0.5 h	none					
		twice					
	4 h	none					
		twice					
supernatant 0.5 h	none	none					
		twice					
supernatant 4 h	none	none					
		twice					
computed for β-LGB							

Computation

O_{org} and O_{inorg} from XPS spectra

adlayer = C_{tot} + N + O_{org}

substrate = Fe + Cr + O_{inorg}

3. Results & discussion

Surface chemical composition

Conditioning liquid	Heating	Rinsing	Proportion (%) of elements due to adlayer	Proportion (%) of elements due to substrate	Molar ratios in organic adlayer O_{org}/C_{tot}	Molar ratios in organic adlayer N/C_{tot}	Molar ratios in organic adlayer O_{org}/N
none	none		55	45	…	…	…
	4 h		58	42	…	…	…
β-LGB	none	none	96	4	…	…	…
		twice	81	19	…	…	…
	0.5 h	none	96	4	…	…	…
		twice	78	22	…	…	…
	4 h	none	101	-1	…	…	…
		twice	103	-3	…	…	…
supernatant 0.5 h	none	none	98	2	…	…	…
		twice	94	6	…	…	…
supernatant 4 h	none	none	82	18	…	…	…
		twice	77	23	…	…	…
computed for β-LGB			100	0	…	…	…

Bare samples

presence of organic contaminants

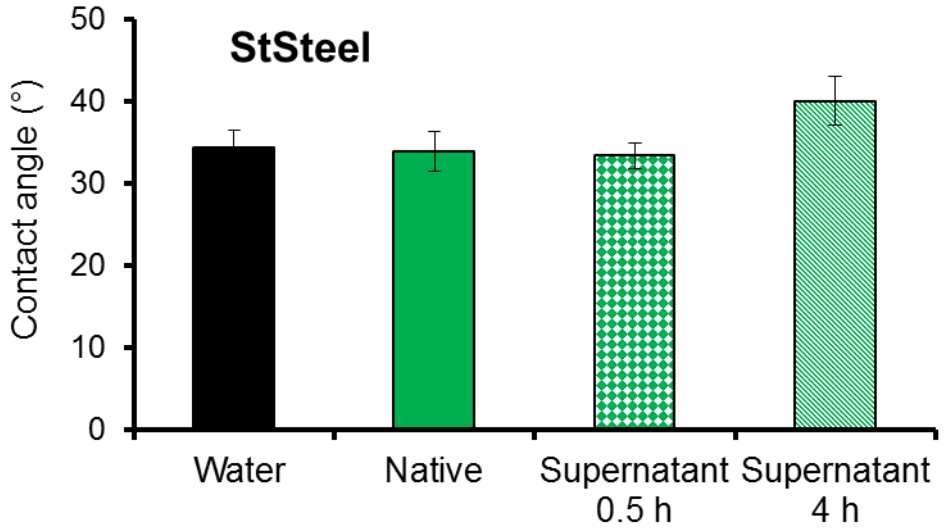
Conditioned samples

- organic layer: dominated by protein
- rinsing : weak desorption, same as BSA and others substrates

➔ β-LGB, not quickly desorbed during cleaning test

3. Results & discussion

Contact angle

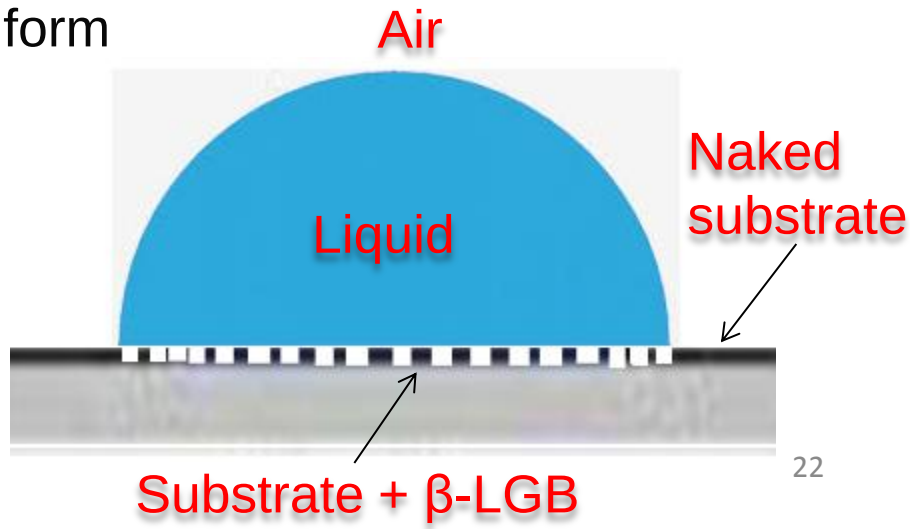


Water contact angle

higher than expected for surface consisting of chromium and iron oxides:
presence of organic contaminants

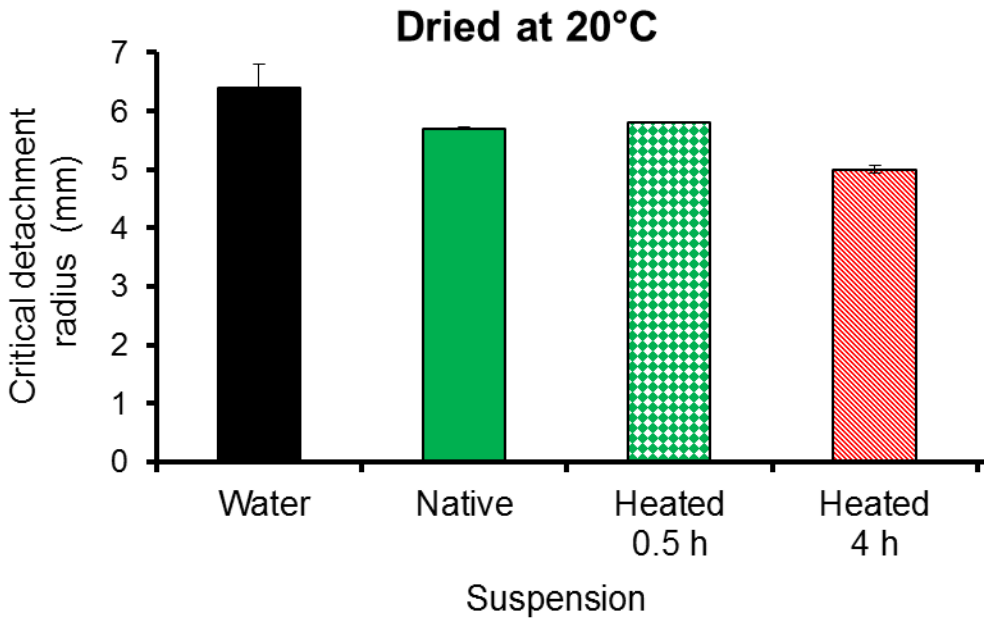
Supernatant 4 h

low concentration of β-LGB, denatured form
contact angle slightly higher
difficult to interpret:
4 phases instead of 3



3. Results & discussion

Critical detachment radius

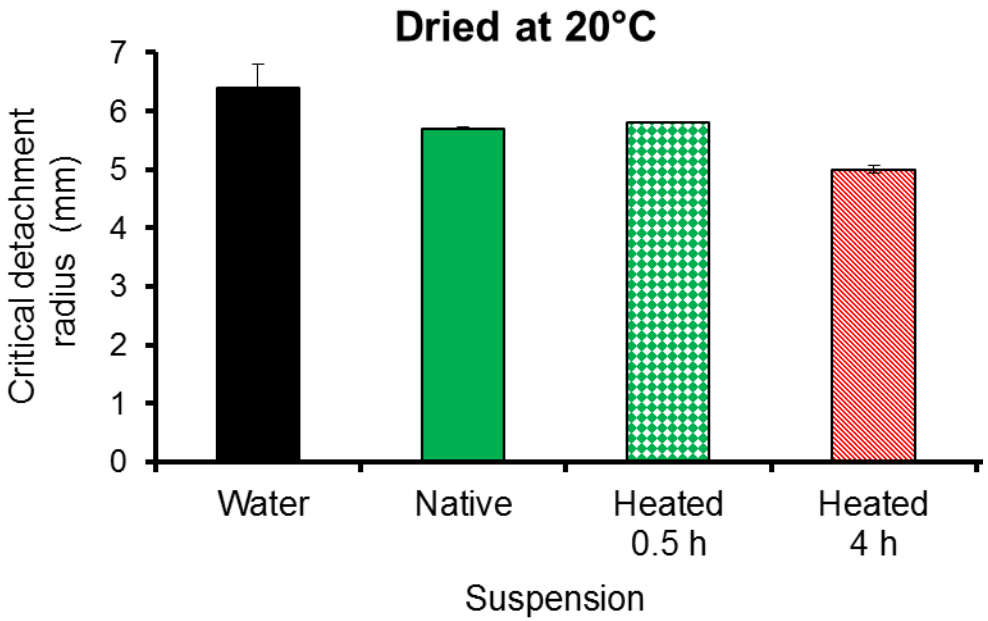


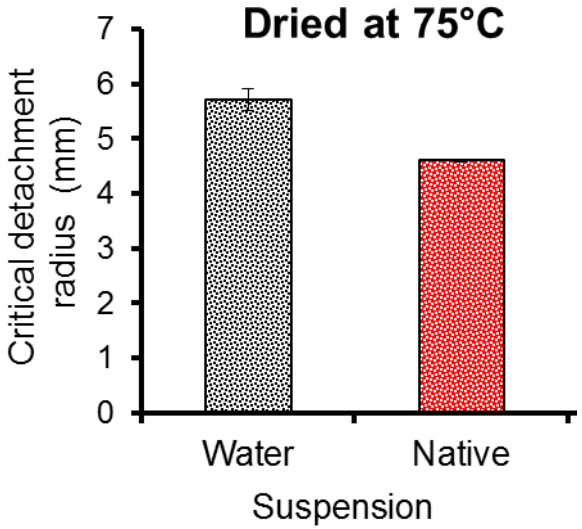
Presence of β-LGB :

- native : decrease of critical detachment radius
  = higher adherence
- denatured (heated 4 h) : further increase of adherence

3. Results & discussion

Critical detachment radius



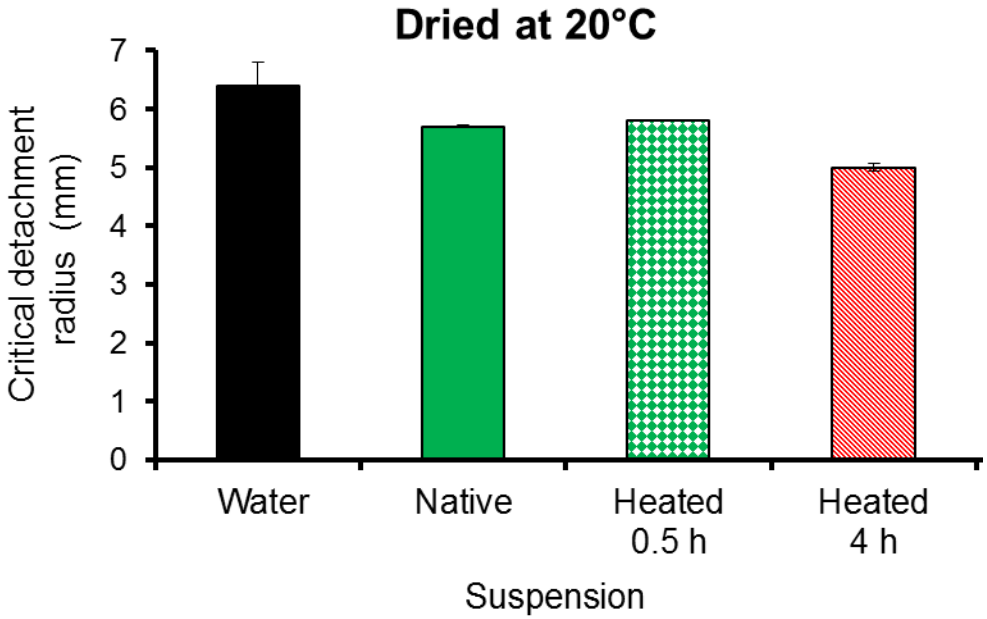


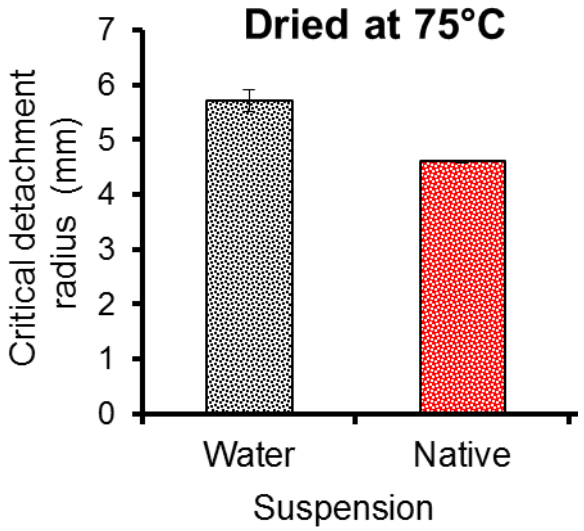
Heating after soiling with

- **suspension in water**
  higher adherence
  ↔ capillary forces
- **suspension in native β-LGB**
  still higher adherence

3. Results & discussion

Critical detachment radius





Presence of β-LGB

- slightly increased adherence
- contradiction with

BSA/glass, β-LGB/glass , β-LGB/stainless steel cleaned UVO

due to surface contamination with organic compounds

Presence of denatured β-LGB

further increased adherence of soiling particles

4. Conclusion

Presence of β-LGB:

- **in soiling quartz particles suspension,**
  - adsorption and domination of in organic layer
  - limited desorption upon rinsing
- **at the quartz particle/stainless steel interface,**
  particle adherence ↗, enhanced by denaturation

Stainless steel vs systems investigated before:

protein influence via
- droplet spreading
- soiling particles aggregation

⊢→ minor importance with respect to direct effects at interface

Remark on influence of stainless steel surface state

stainless steel does not behave as a hydrophilic substrate
owing to surface contamination with organic compounds

Broader study, including substrate hydrophobicity is under way

Thank you for your attention!
Are there any questions?