Cellulose Nanomaterials in Single and Coaxial Filaments Produced by Wet Spinning For Biomedical Applications

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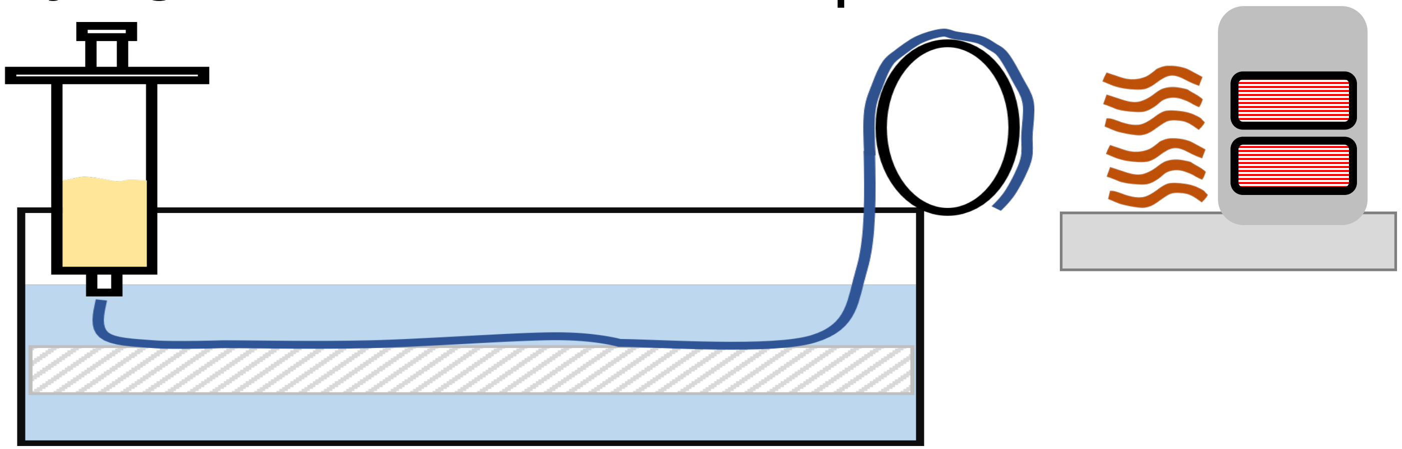
TAPPI NANO DIVISION

Wet spinning

Apparatus



Low-cost approach for filament production

Possible precursors:
polymeric solutions or gels (hydro, organo, iono)

Intended applications:
biomedical devices, textiles

Wet spinning

Precursor: hydrogel

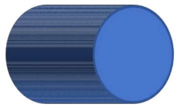
Product: absorbent filament

SEVERAL variables:

- Injection rate
- Conveyor belt rate
- Type of the filaments
- Composition of the filaments
- Type of the coagulant solvent
- Possible additives

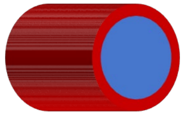
In our case:

Uniaxial filaments (monolithic)



- CNF-based hydrogel

Coaxial filaments (core shell)



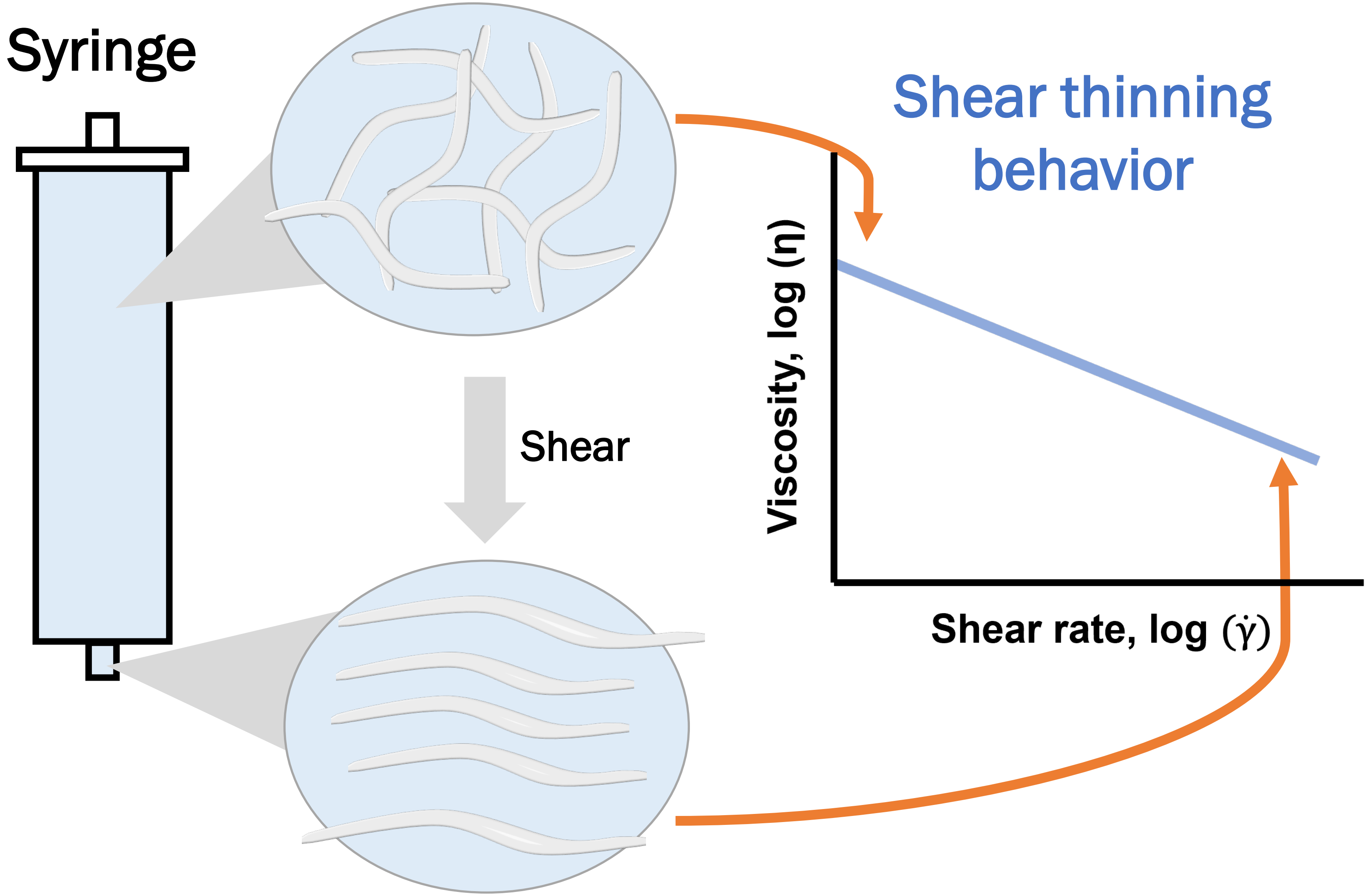
Core:

- Oil
- Emulsions
- CNF-based Hydrogel

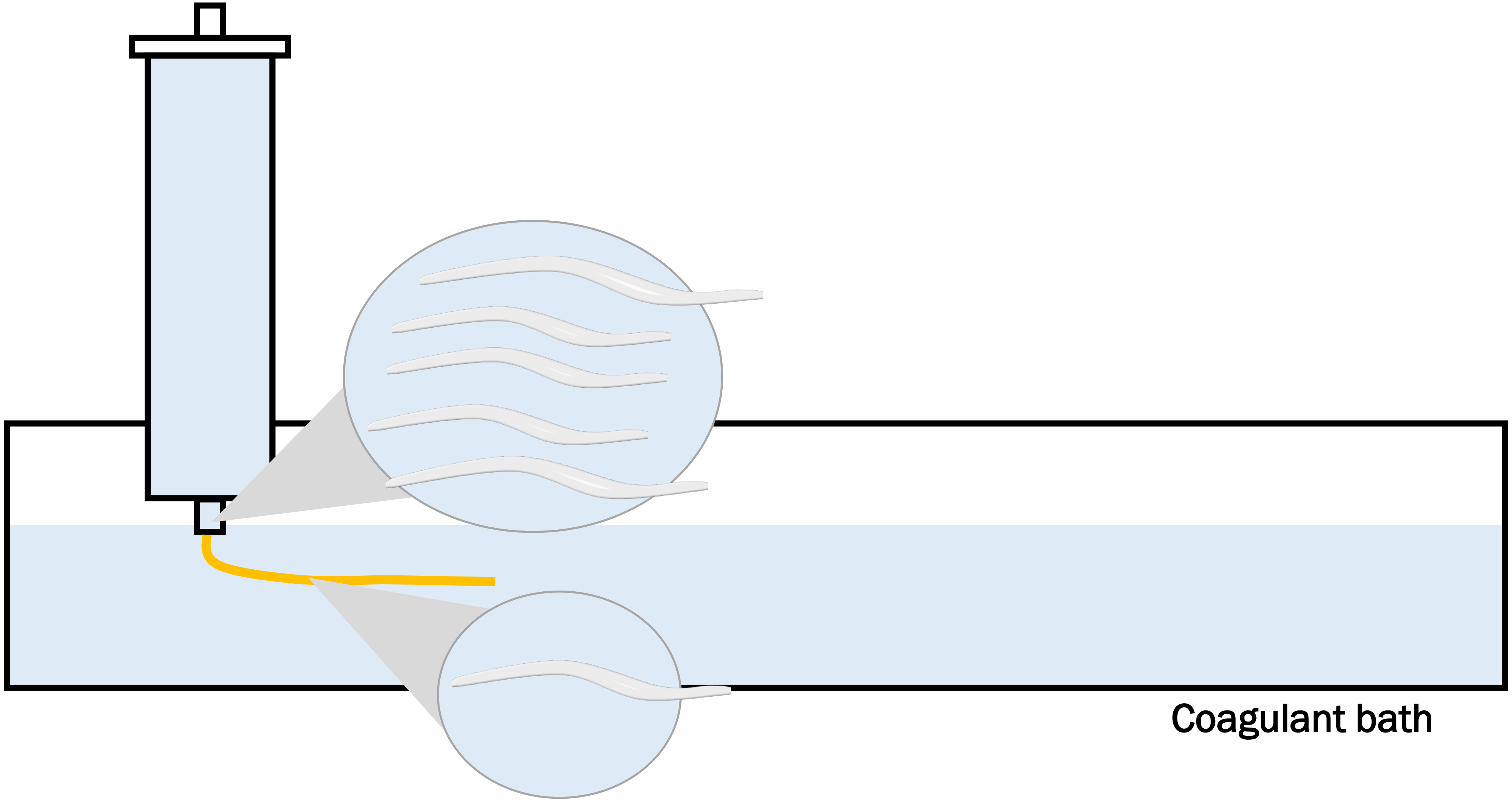
Shell:

- Methylcellulose -CNC hydrogel

Hydrogels in wet spinning

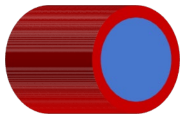


Hydrogels in wet spinning



Possibilities in nanocellulose uses:

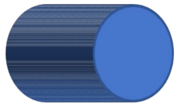
Coaxial filaments (core shell)



Core:
- Oil
- Emulsions

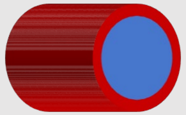
Shell:
- Methylcellulose-CNC hydrogel

Uniaxial filaments (monolithic)



- CNF-based hydrogel

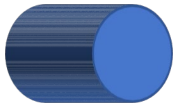
Coaxial filaments (core shell)



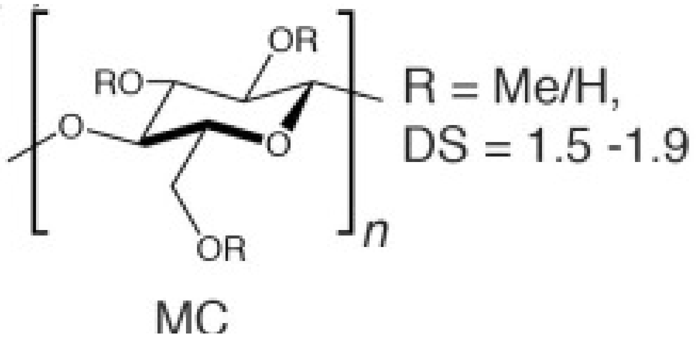
Core:
- Oil
- Emulsions

Shell:
- Methylcellulose-CNC hydrogel

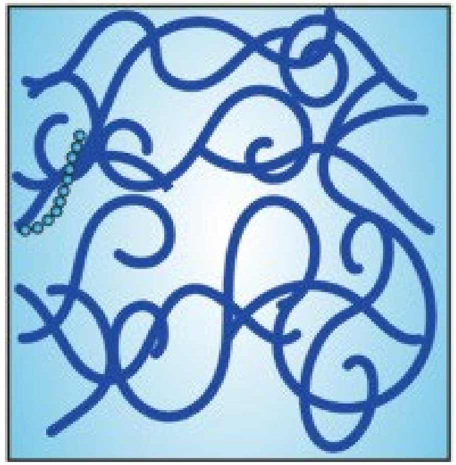
Uniaxial filaments (monolithic)



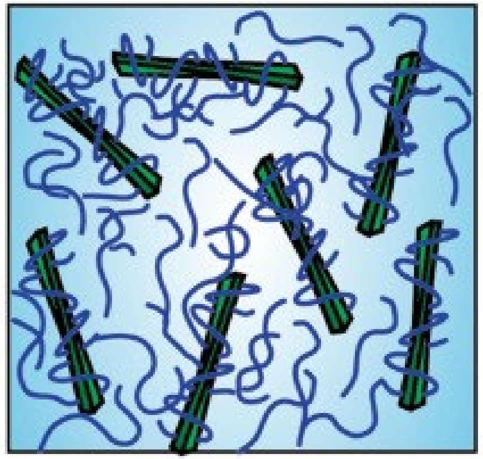
- CNF-based hydrogel



Hynninen et al., European Polymer Journal, 112, 334, 2019



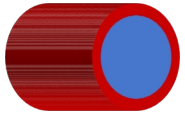
Methylcellulose (MC)



MC + CNC

❶ Oil-filled filaments

- New approach for oil encapsulation



Coaxial filaments

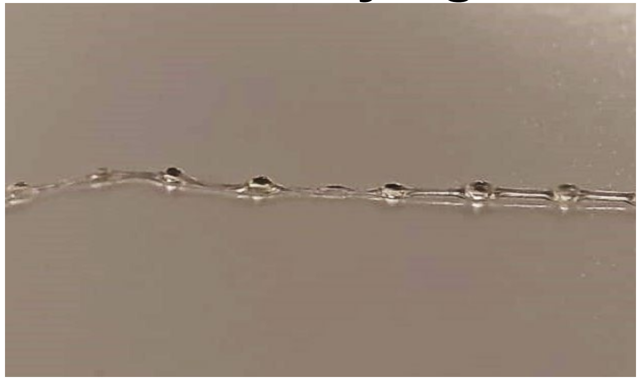
Core:
Corn oil

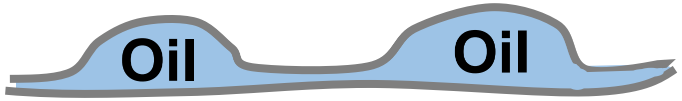
Shell:
MC-CNC

Injection:

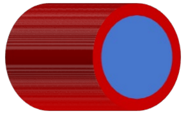
Drying:

After drying:





❶ Oil-filled filaments

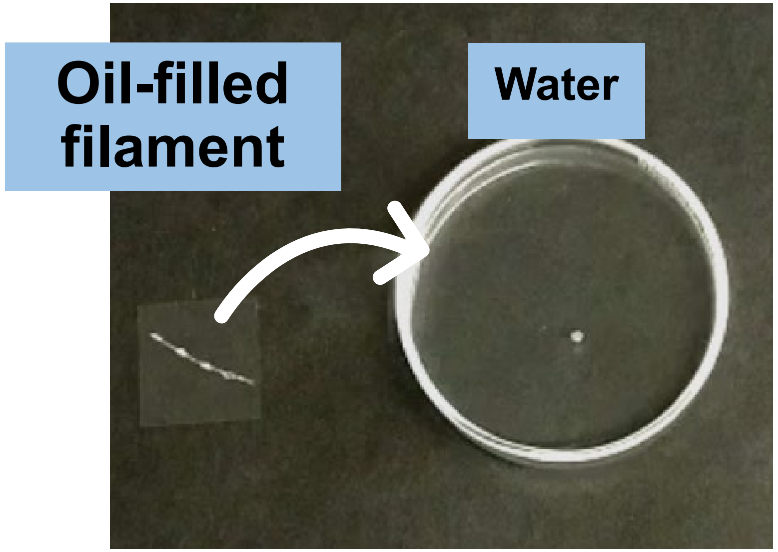


Coaxial filaments

Core:
Corn oil

Shell:
MC-CNC

Water absorption:



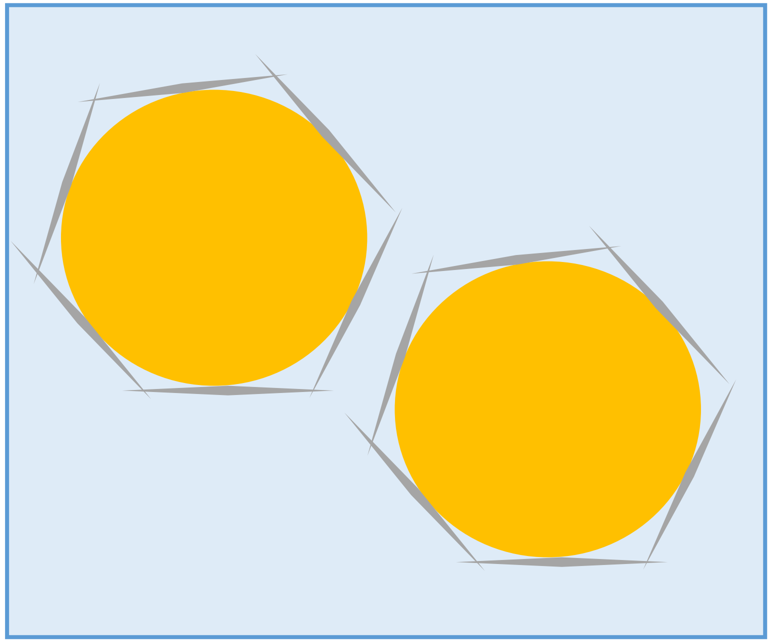
1 min

Can we modulate the filament morphology by adding emulsions instead of pure oil?

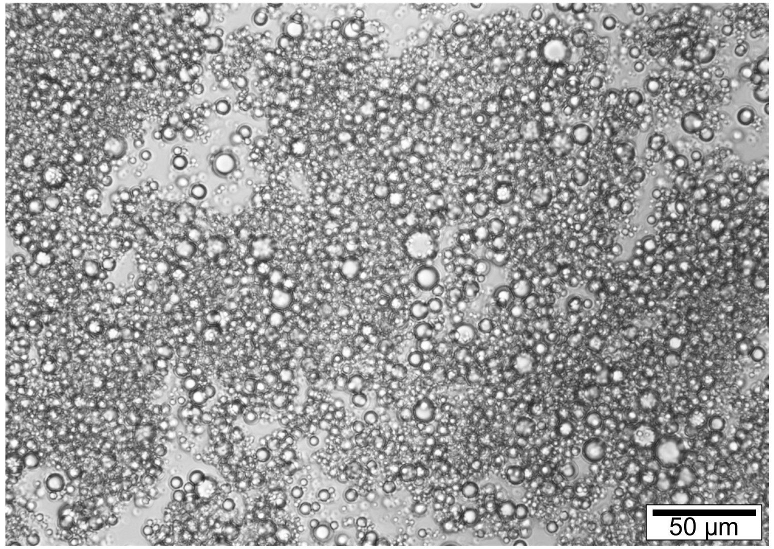
Emulsion preparation

Pickering emulsion

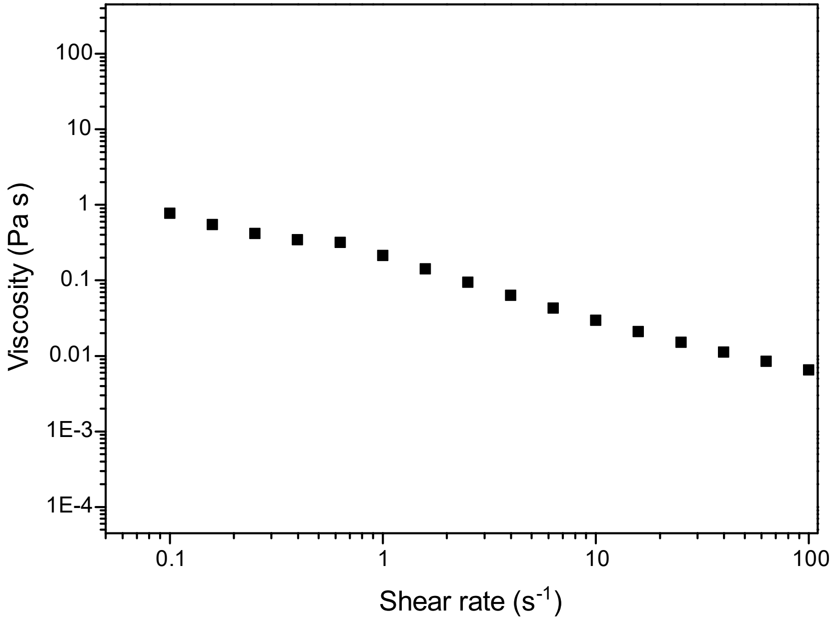
- Oil in water (20:80)
- CNC (0.25 wt.%)
- 20 mM HEPES buffer and 50 mM NaCl in the water phase



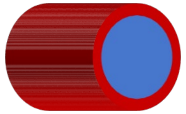
Optical microscopy



Rheology



❷ Pickering emulsion-filled filaments



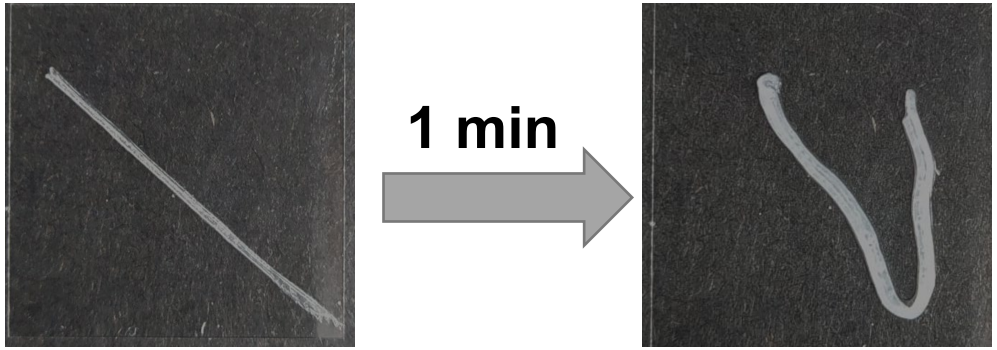
Coaxial filaments

Core:
CNC Pickering emulsion (0.25%)

Shell:
MC-CNC

Injection:

Water absorption:

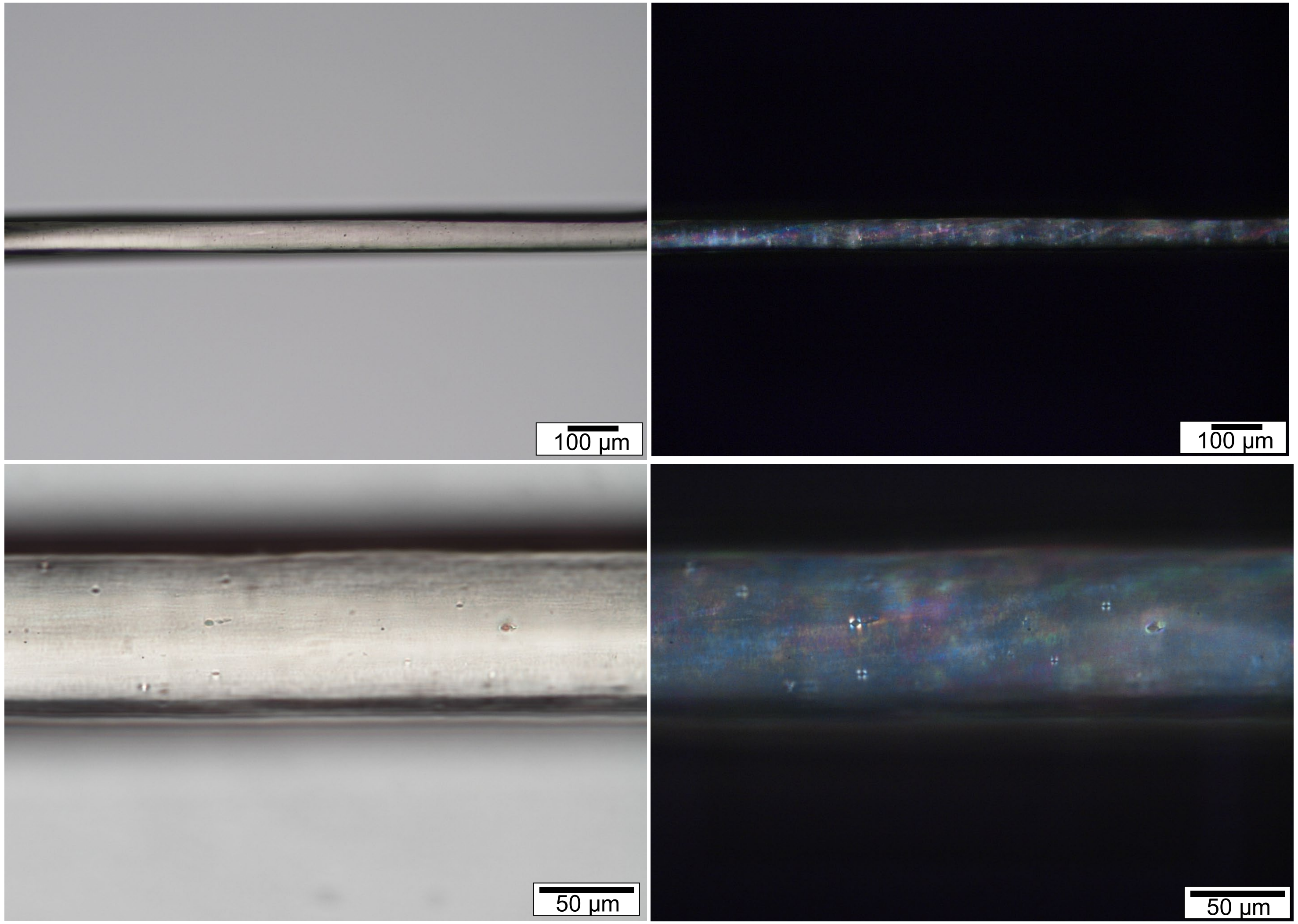


Continuous filaments

- Possibility of encapsulation of actives in the emulsion

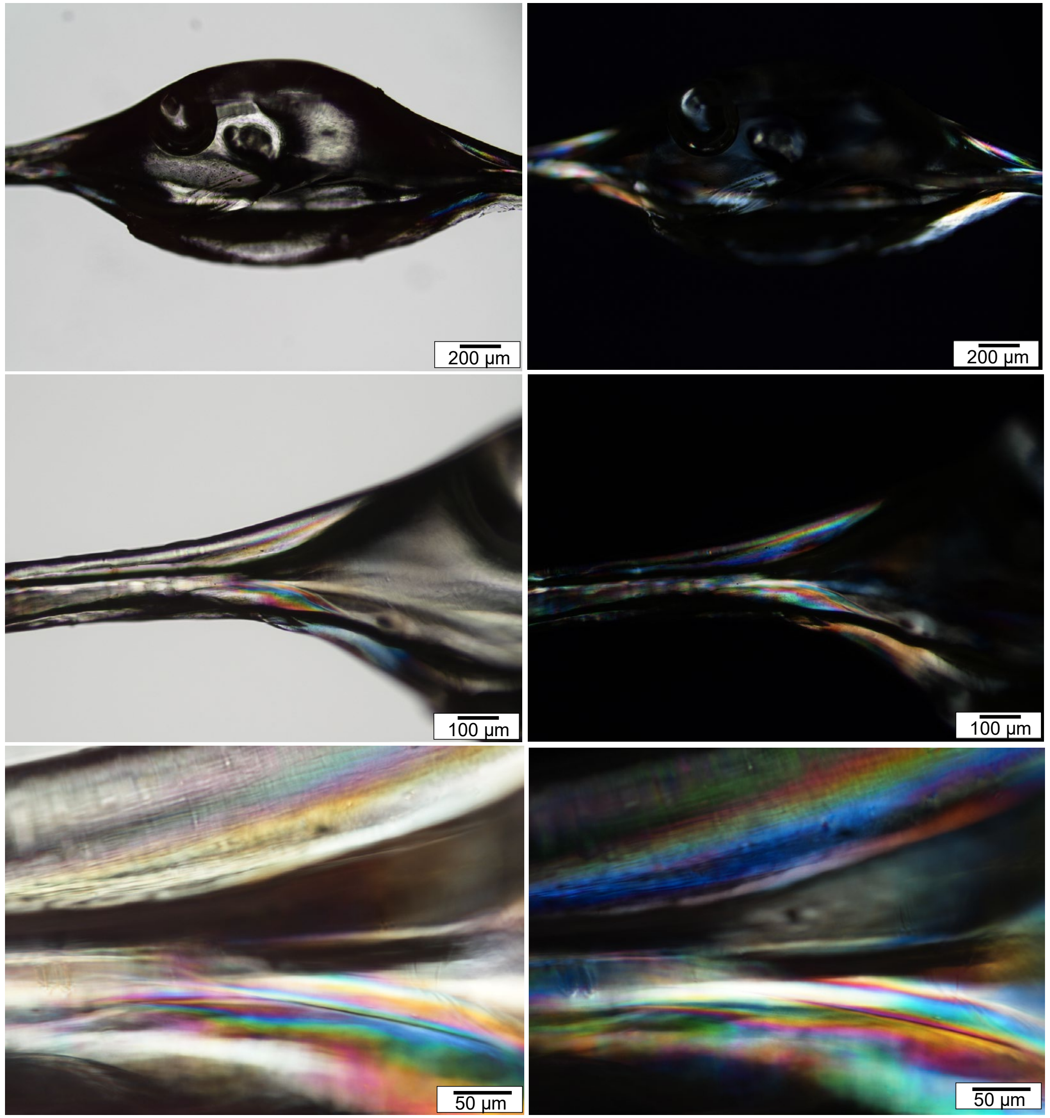
Filament characterization

Only MC-CNC sheet

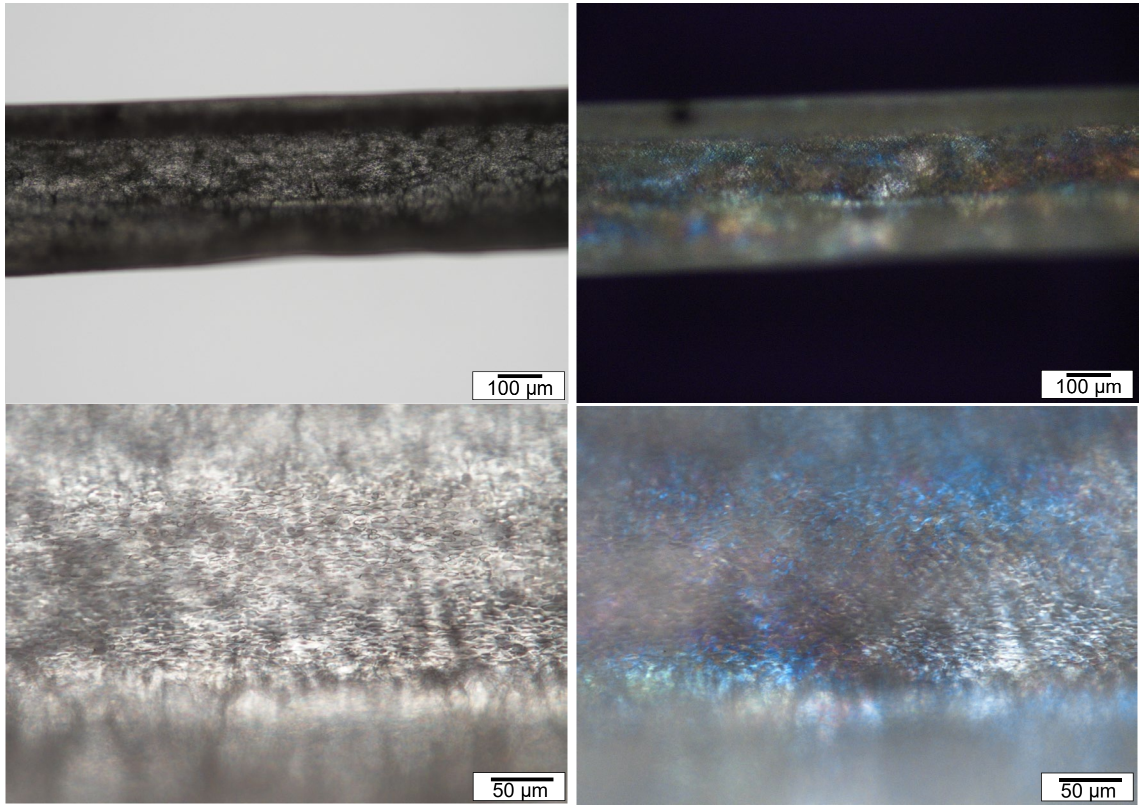


Filament characterization

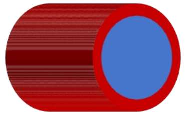
Oil-filled filament



Emulsion filament



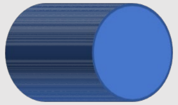
Coaxial filaments (core shell)



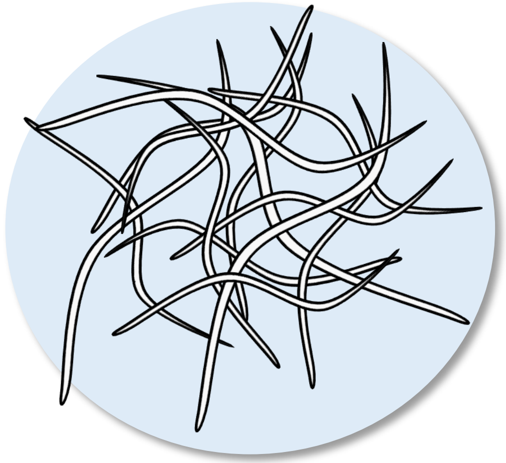
Core:
- Oil
- Emulsions

Shell:
- Methylcellulose-CNC hydrogel

Uniaxial filaments (monolithic)



- CNF-based hydrogel



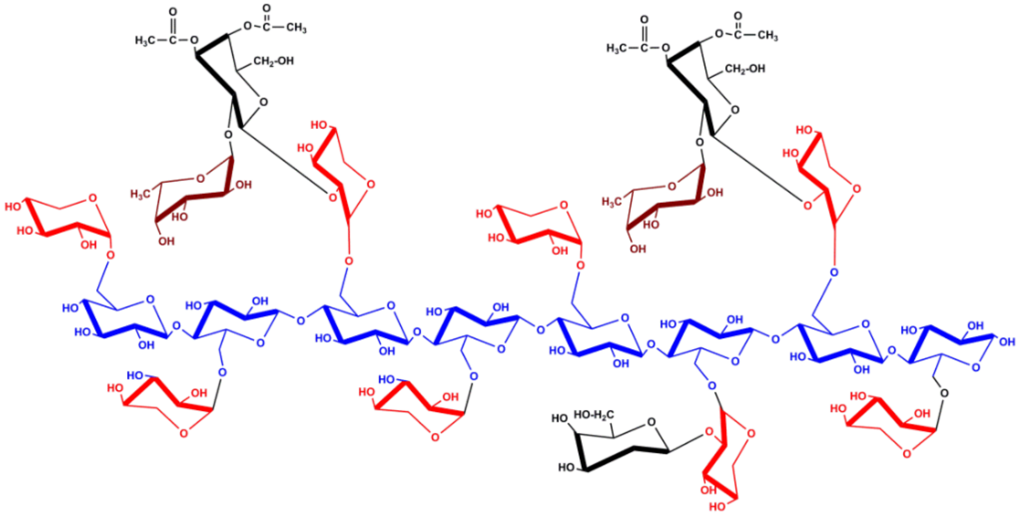
Cellulose nanofibrils (CNF)

Long (500 nm–2 μm)
Flexible
Easy to entangle
Gel formation: 1 wt.%

Only CNF and water (concentration: 1 wt.%)

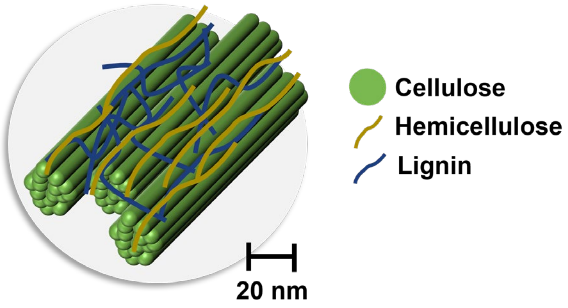
Xyloglucan (XG)

Hemicellulose derivative
Branched polysaccharide

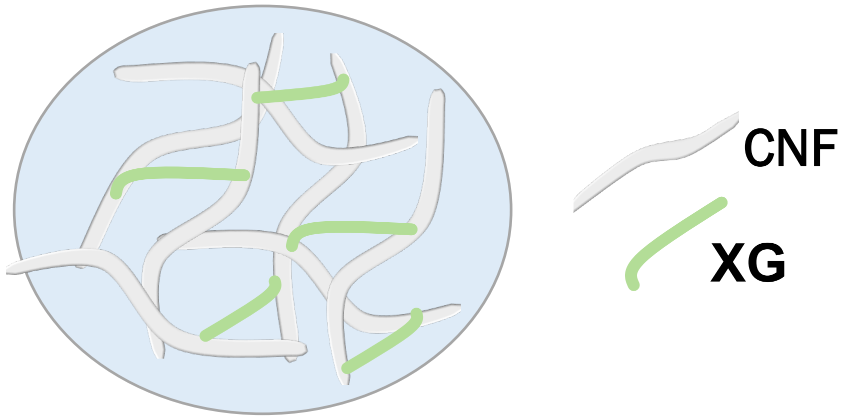


β-D-glucan (backbone)
α-D-xylose
α-D-Galactose
α-L-fucose

Close interaction with cellulose in plant cell wall



Possibilities to use XG to modulate CNF hydrogel properties



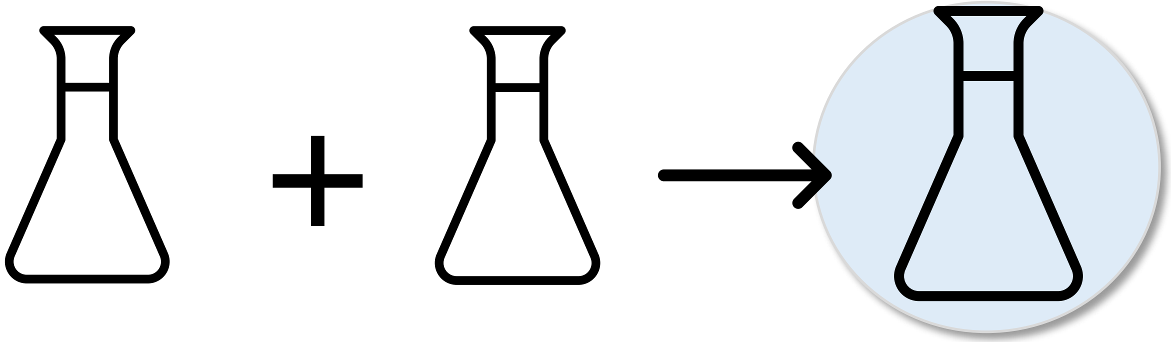
Is it possible to produce filaments of CNF-XG hydrogels by wet spinning?

Ochoa-Villarreal *et al*. Plant cell wall polymers: Function, Structure and Biological Activity of Their Derivatives (2012)

CNF-XG hydrogel preparation

Xyloglucan from tamarind seed

Hydrogel preparation



CNF dispersion

0.5 and 1 wt.%

XG solution

0 to 0.5 wt.%

CNF-XG hydrogel

Characterization

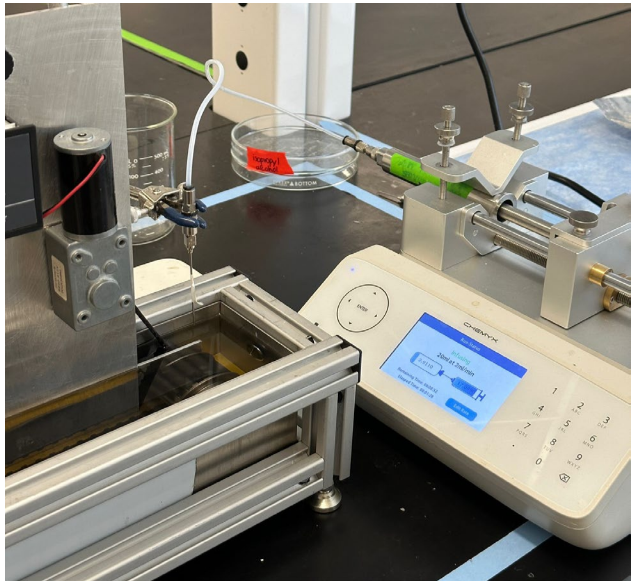
Rheology

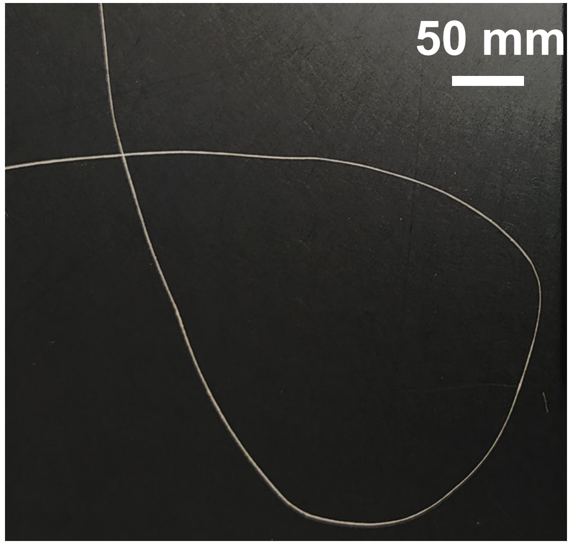
Accelerated stability (LUMiSizer)

Application

Filament production (wet spinning)

Wet spinning

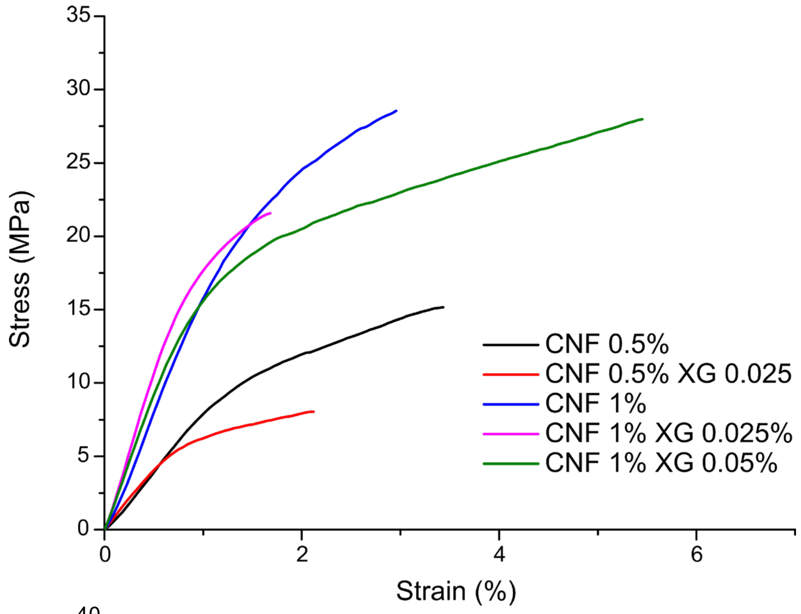


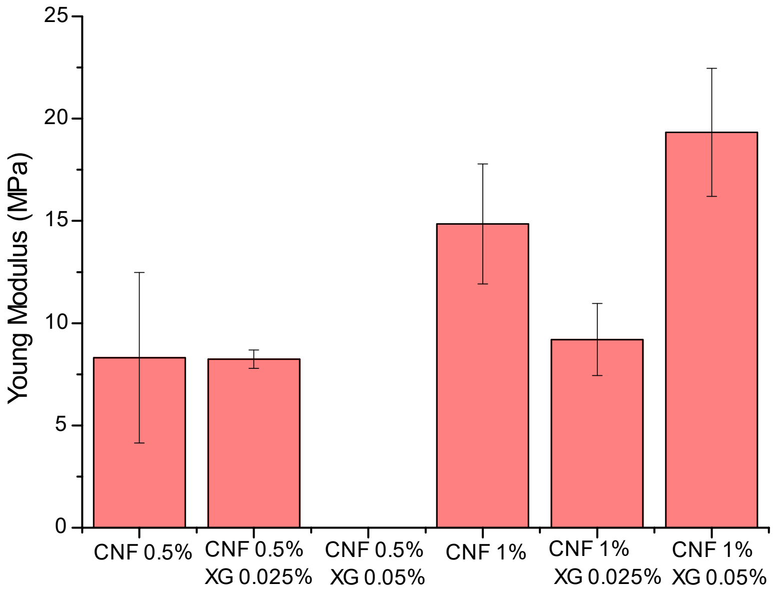


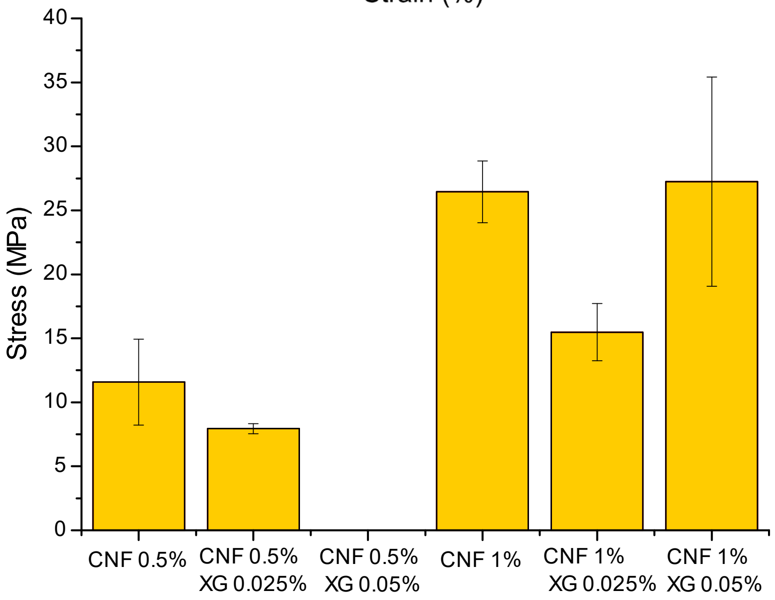
Coagulant bath: isopropyl alcohol

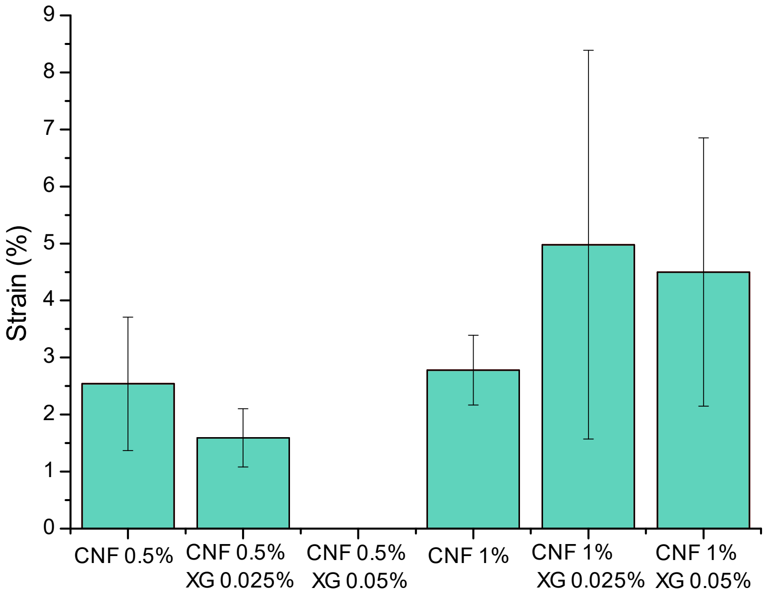
Injection rate: 0.5 mL/min

Mechanical analysis (ongoing)





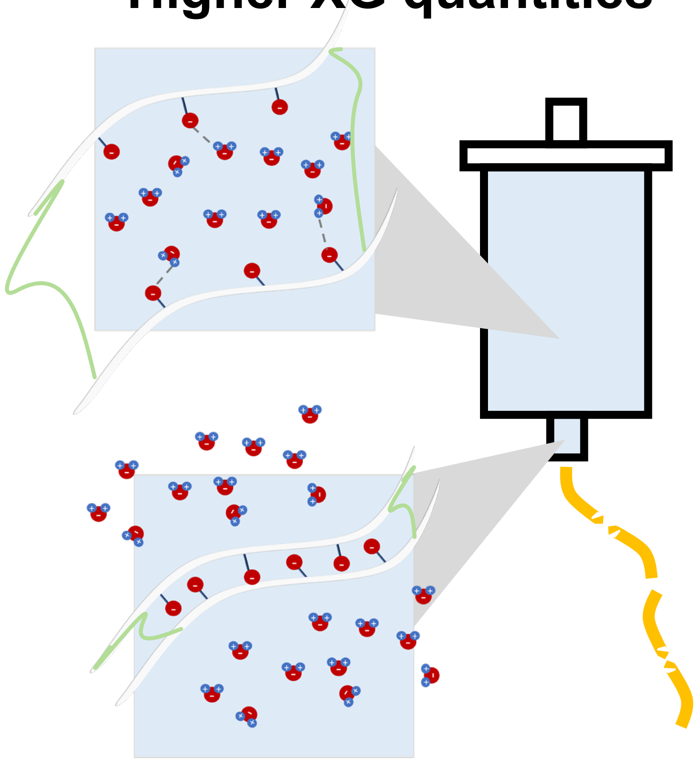




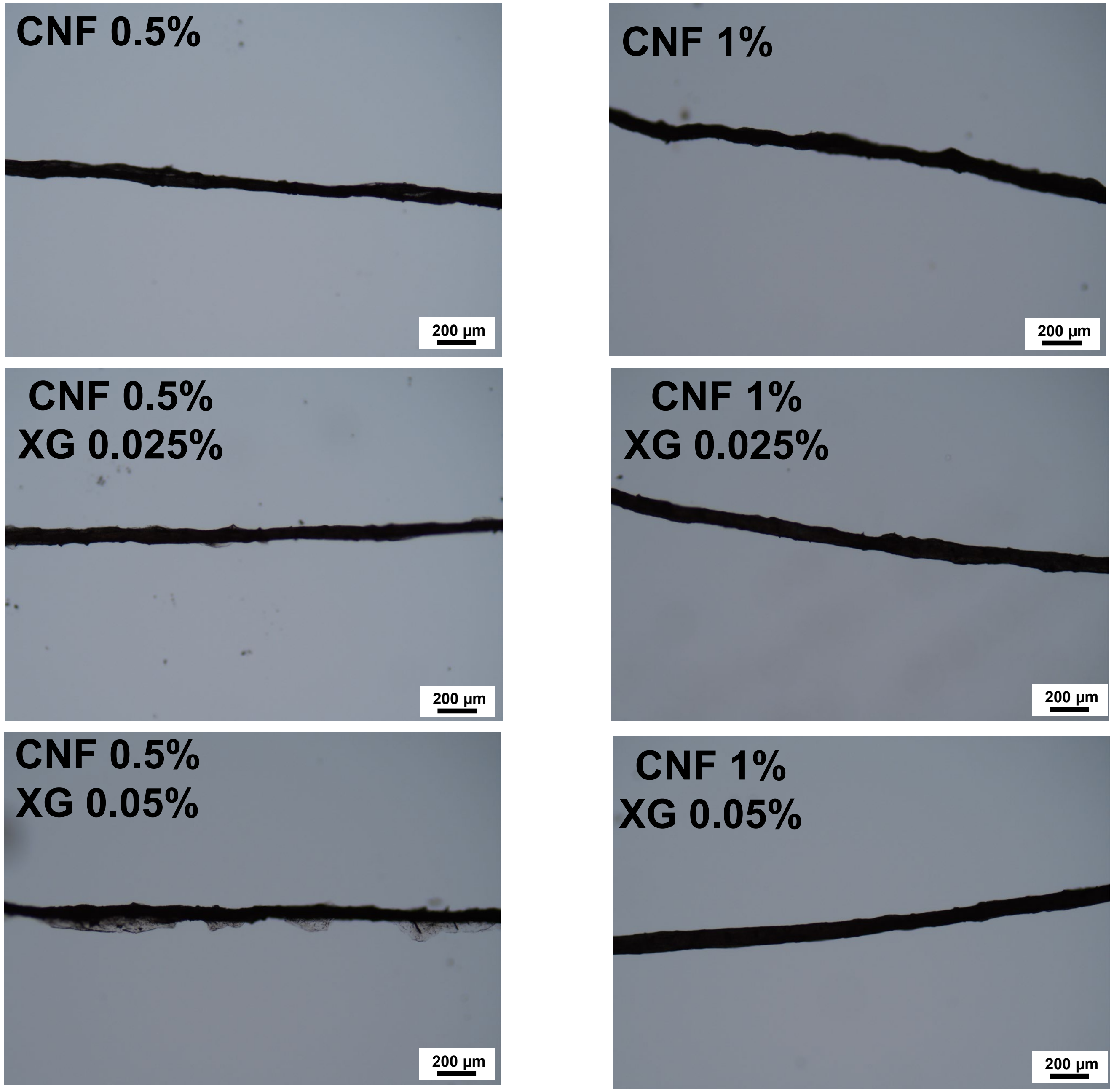
Wet spinning

Injection process induces water release

Higher XG quantities



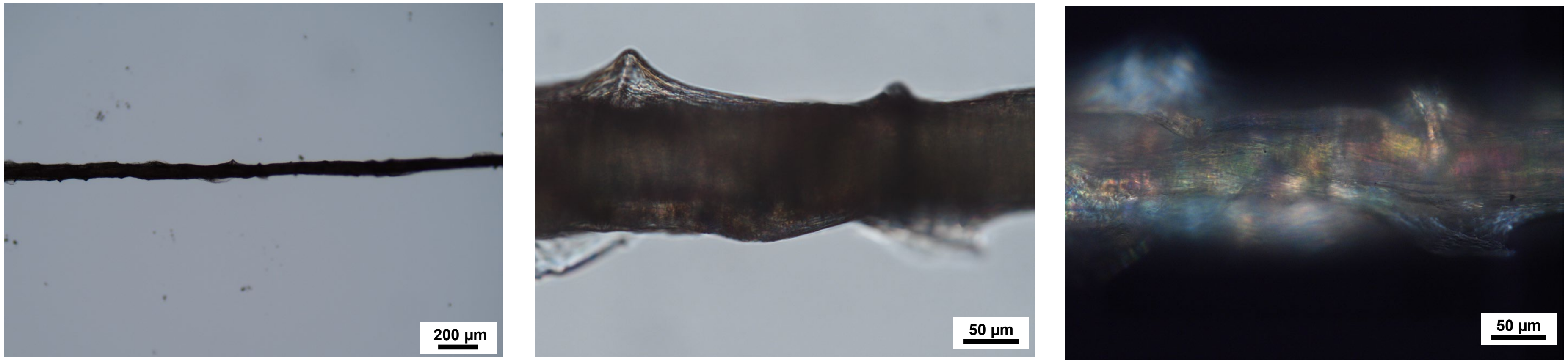
Lower quantities of XG enable the production of filaments



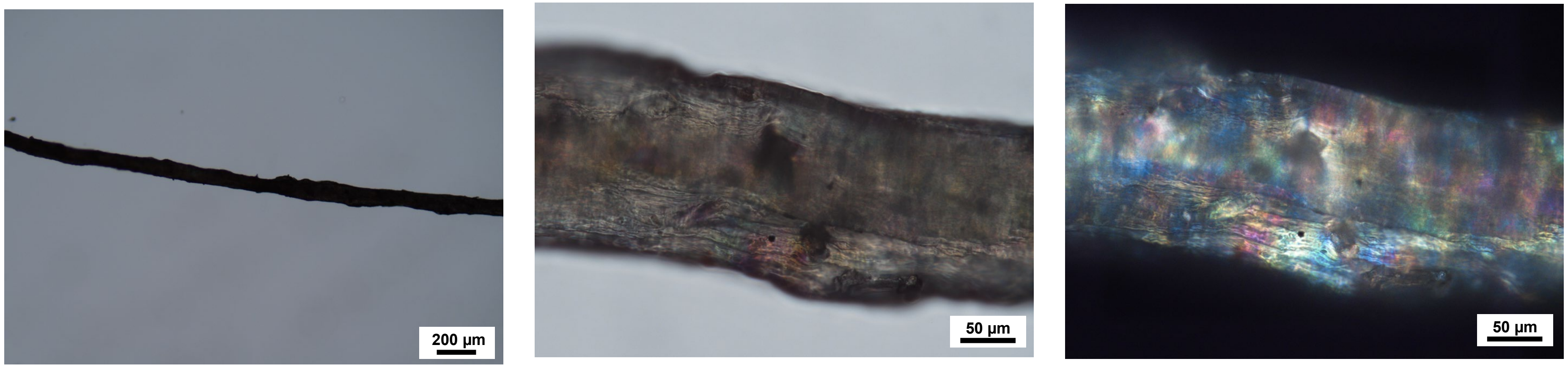
Wet spinning

Polarized optical microscopy

CNF 0.5%
XG 0.025%



CNF 1%
XG 0.025%



Injection promotes CNF alignment

Conclusions

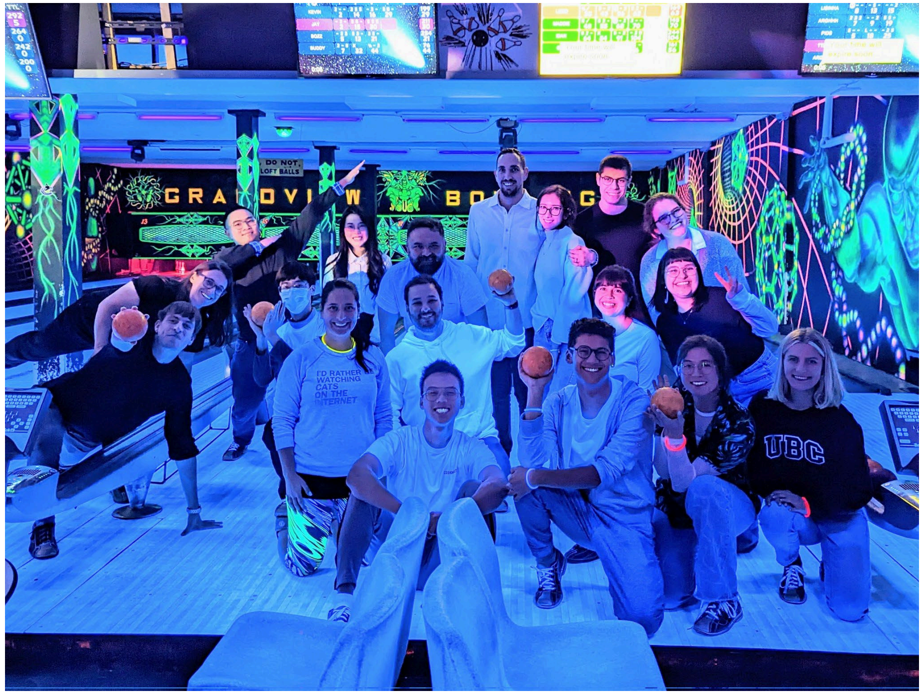
Acknowledgments

UNICAMP

LaQuiMoBio

UBC

Sustainable NaNO BiO Composites



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