Evaluation of Different Cellulose Nanofibrils (CNFs) as a Replacement for Xanthan Gum (XGD) in Water Based Drilling Fluids (WBMs) to be Used in Shale Formations

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7° CONGRESO IAPG
Producción y Desarrollo de Reservas

INTEC

UNL

CONICET

5 – 8 de Noviembre 2019
Mar del Plata, Argentina

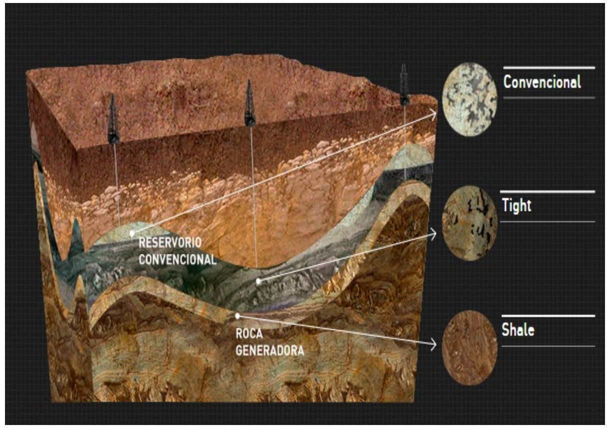
INSTITUTO ARGENTINO DEL PETROLEO Y DEL GAS

Outline

- Introduction
- Objectives
- Experimental and theoretical work
- Conclusions

Hydrocarbon Exploitation

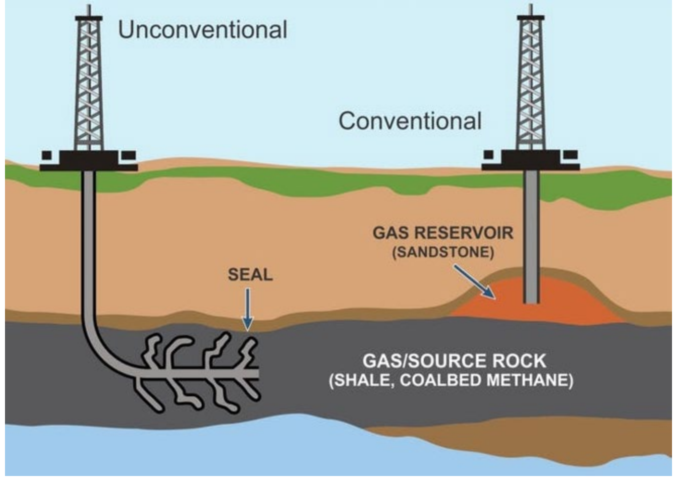
- Conventional Reservoirs
- Unconventional reservoirs → SHALE →

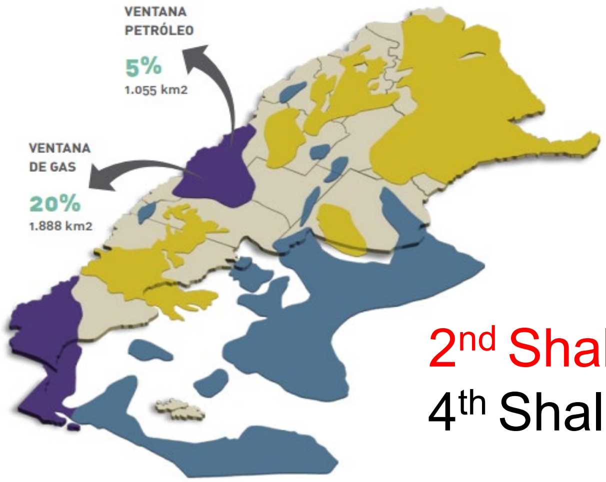


✓ Low pemeability
✓ The hydrocarbons are trapped within the formation

Energy Deficit

High consumption:
✓ Energy
✓ Materials derivates from petroleum





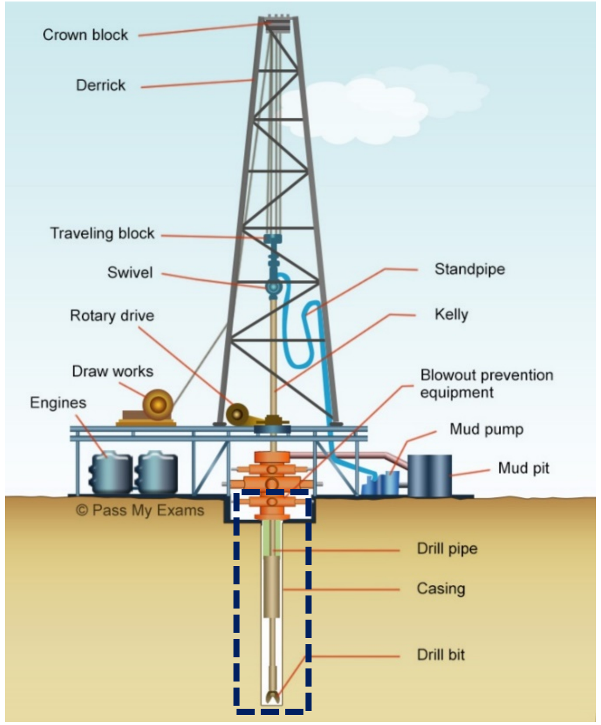
2nd Shale Gas
4th Shale Oil

Operation-Stages-Drilling Fluids

- Exploration
- **Drilling**
- Termination
- Production

Drilling Fluids

✓ Transport the cuttings to surface
✓ Control pressures
✓ Preserve wellbore stability
✓ Cool and lubricate tools
✓ Transmit hydraulic energy



Physical properties of fluids

- **Rheological**

Shear thinning

Viscosity range (40-50mPa.s)

Viscoelastic behavior

- **Filtration**

Filtrate volume (<10 mL)

Low permeability

Thickness of filter cake (< 6 mm)

- **Thermal**

Thermal stability

- **Others..**

Density

Environmental behavior

Drilling Fluids-Types

- Liquid
  - **OBM** "Oil based mud"
    - ✓ Thermal stability
    - ✓ Shale inhibition
    - ✓ Lubricity
    - x **High environmental impact**
  - **WBM** "Water based mud"
    - ✓ **Low environmental impact**
    - x **Fluid-clay interactions (wellbore stability)**
- Gas

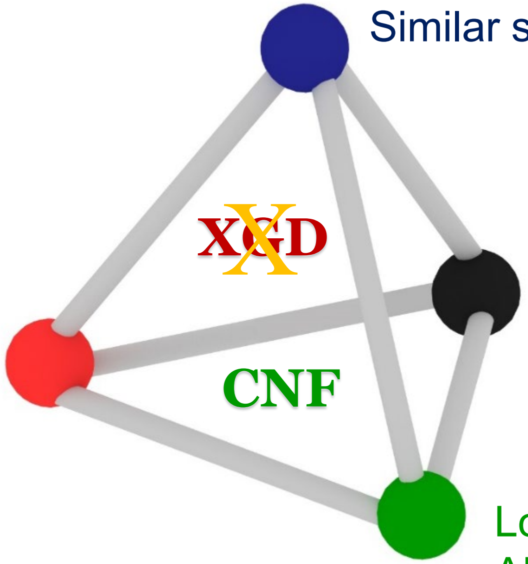
Adittional additives: polymers and inorganics

Objectives

- To design WBMs with rheological properties similar to the OBMs used in shale formations of Argentina.
- To study the use of different cellulose nanofibrils (CNFs) as a replacement of xanthan gum (XGD) in WBMs.
- To evaluate the effect of CNFs on the main functional properties of WBMs(rheological, filtration, thermal and structural properties).

Similar structural and physical characteristics to XGD

XGD is imported in Argentina



Alternative to synthetic polymers and conventional biopolymers
Different aplications in petroleum industry
Potential low cost

Low environmental impact
Abundant, renewable and sustainable polymer

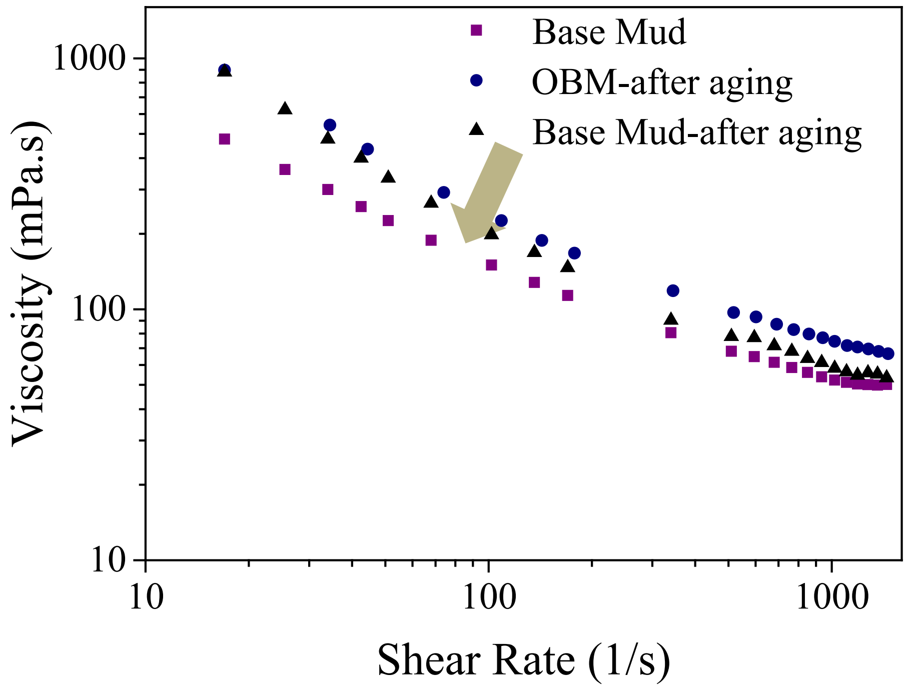
Base Mud-Design

Base mud composition

Order of Addition	Component	Dosage	Function
1	Na-Bentonite		Base
	A		Viscosifier and filtration control agent
2	Polyanionic cellulose (PAC)	8.00 g/L	Filtration control agent
	Xanthan gum (XGD)	1.50 g/L	Viscosifier
	B		Encapsulator
	C		Inhibitor
3	D		Lubricant
4	E		Filtration control agent
	F		Filtration control agent
	G		Densifier
5	H		pH control
6	I		Cuttings

XRD Characterization of Shale (Vaca Muerta)

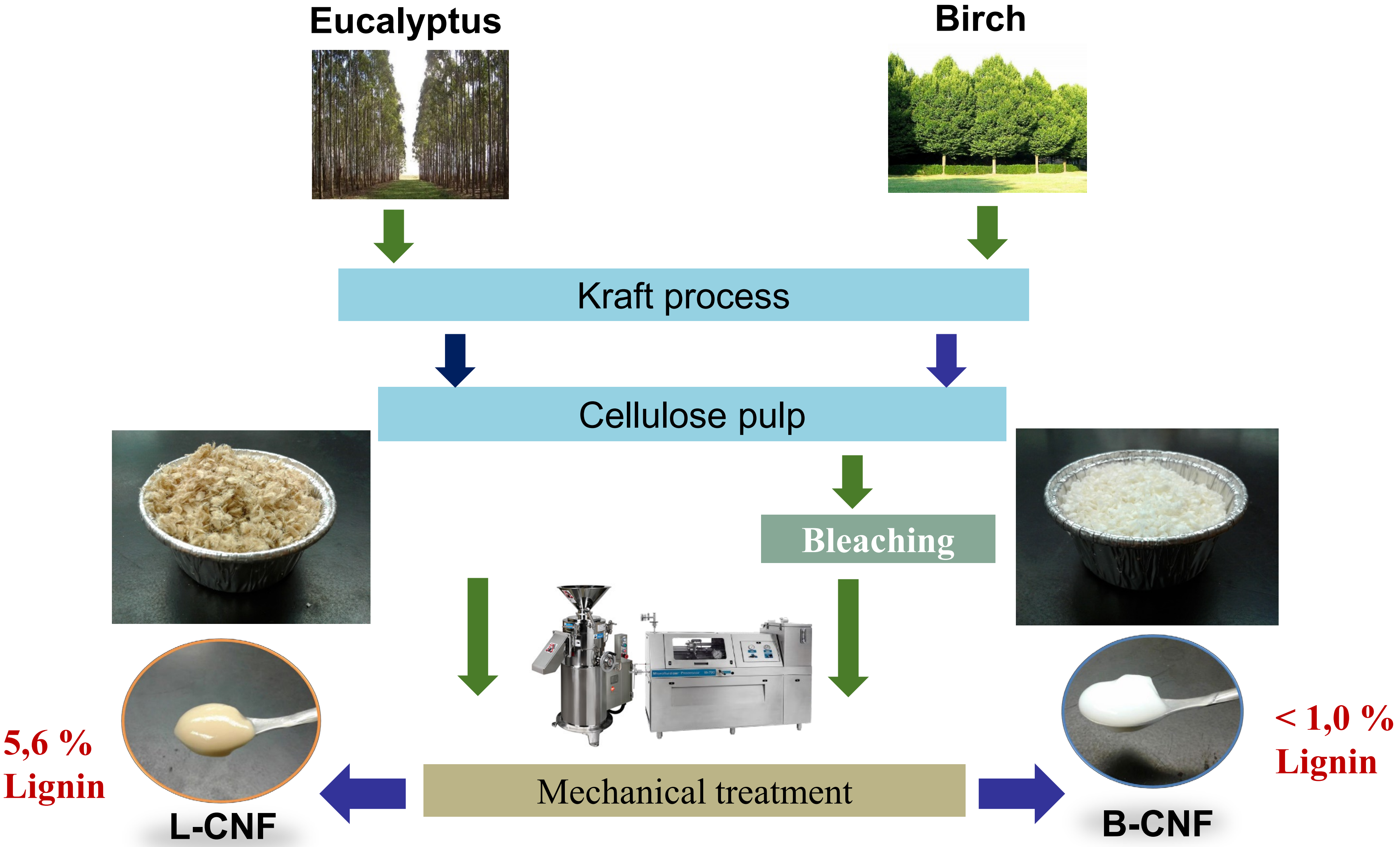
Polymer	$\overline{M_n}$(g/mol)	$\overline{M_w}$(g/mol)
PAC	692.000	1.146.000
XGD	881.000	1.622.000



✓ **WBM with similar rheological properties to OBM**

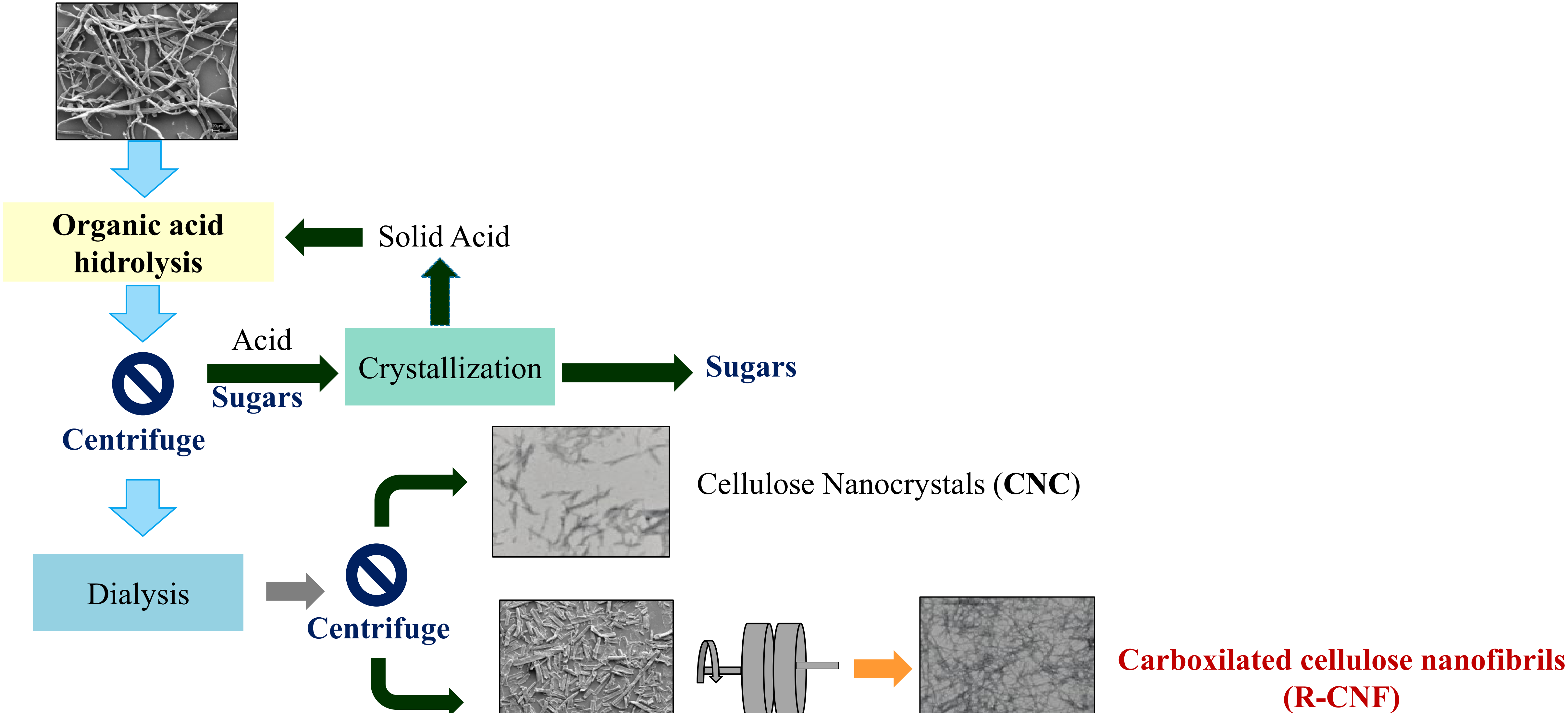
CNFs-Types

L-CNF and B-CNF Isolation



CNFs-Types

R-CNF Isolation

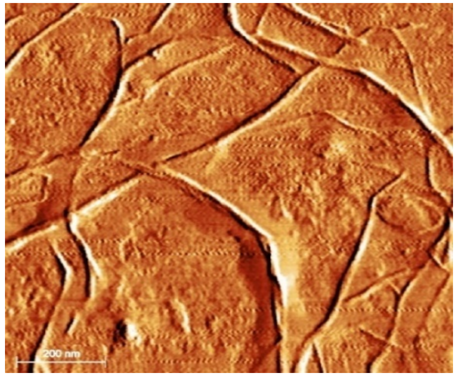


Chen et al. 2016, Green Chem. 18, 3835

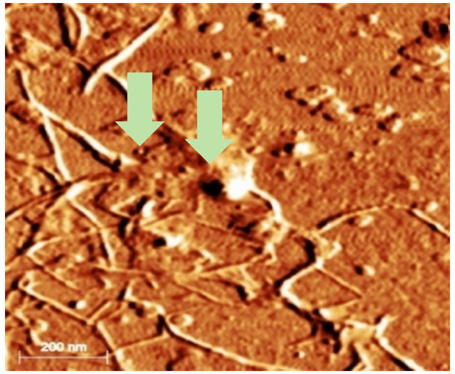
CNFs Characterization

❑ Morphological Characterization

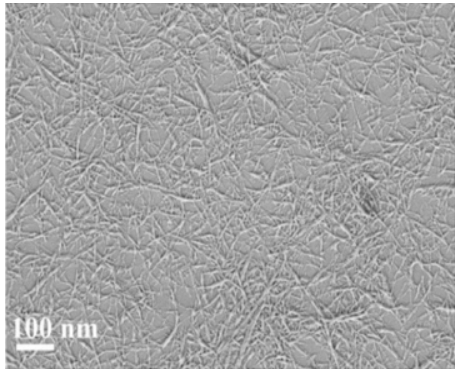
B-CNF



L-CNF



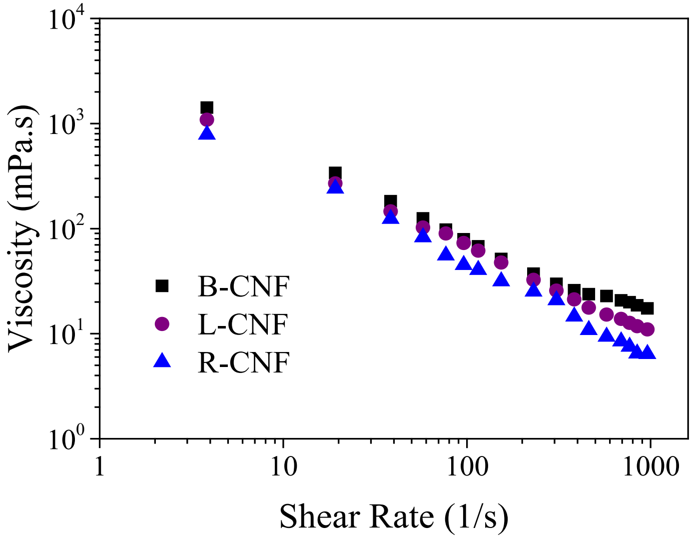
R-CNF



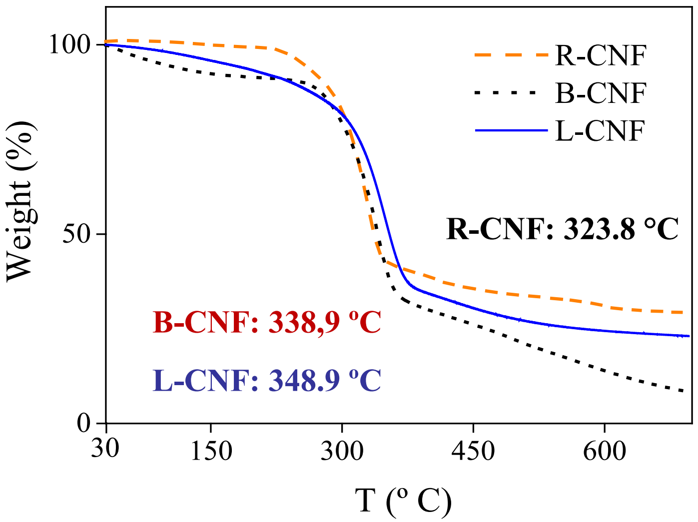
❑ Surface Characterization

Sample	Charge density (μeq/g)	ζ Potential (mV)
B-CNF	-50.11 ± 0.51	-24.70 ± 0.70
L-CNF	-58.00 ± 0.85	-34.70 ± 2.40
R-CNF	-101.00 ± 0.35	-36.21 ± 1.40

❑ Rheological Characterization



❑ Thermal Characterization



- ✓ Lower aspect ratio for R-CNF
- ✓ Higher charge density for R-CNF
- ✓ Higher thermal stability for L-CNF

Preparation of Systems: **BT/CNFs/PAC/H_2O – BT/XGD/PAC/H_2O**

System S-BCNF: BT/B-CNF/PAC/H_2O

Fluid	BT (% m/m)	B-CNF (% m/m)	PAC (% m/m)
1B-CNF	0.00	0.50	0.50
2B-CNF	1.00	0.50	0.50
3B-CNF	3.00	0.50	0.50
4B-CNF	4.50	0.50	0.50
5B-CNF	6.00	0.50	0.50
6B-CNF	4.50	0.00	0.50
7B-CNF	4.50	0.10	0.50
8B-CNF	4.50	0.25	0.50
9B-CNF	4.50	0.50	0 00
10B-CNF	4.5 0	0.50	0.10
11B-CNF	4.50	0.50	0.25

System S-LCNF: BT/L-CNF/PAC/H_2O

Fluid	BT (% m/m)	L-CNF (% m/m)	PAC (% m/m)
1L-CNF	0.00	0.50	0.50
2L-CNF	1.00	0.50	0.50
3L-CNF	3.00	0.50	0.50
4L-CNF	4.50	0.50	0.50
5L-CNF	6.00	0.50	0.50
6L-CNF	4.50	0.00	0.50
7L-CNF	4.50	0.10	0.50
8L-CNF	4.50	0.25	0.50
9L-CNF	4.50	0.50	0.00
10L-CNF	4.50	0.50	0.10
11L-CNF	4.50	0.50	0.25

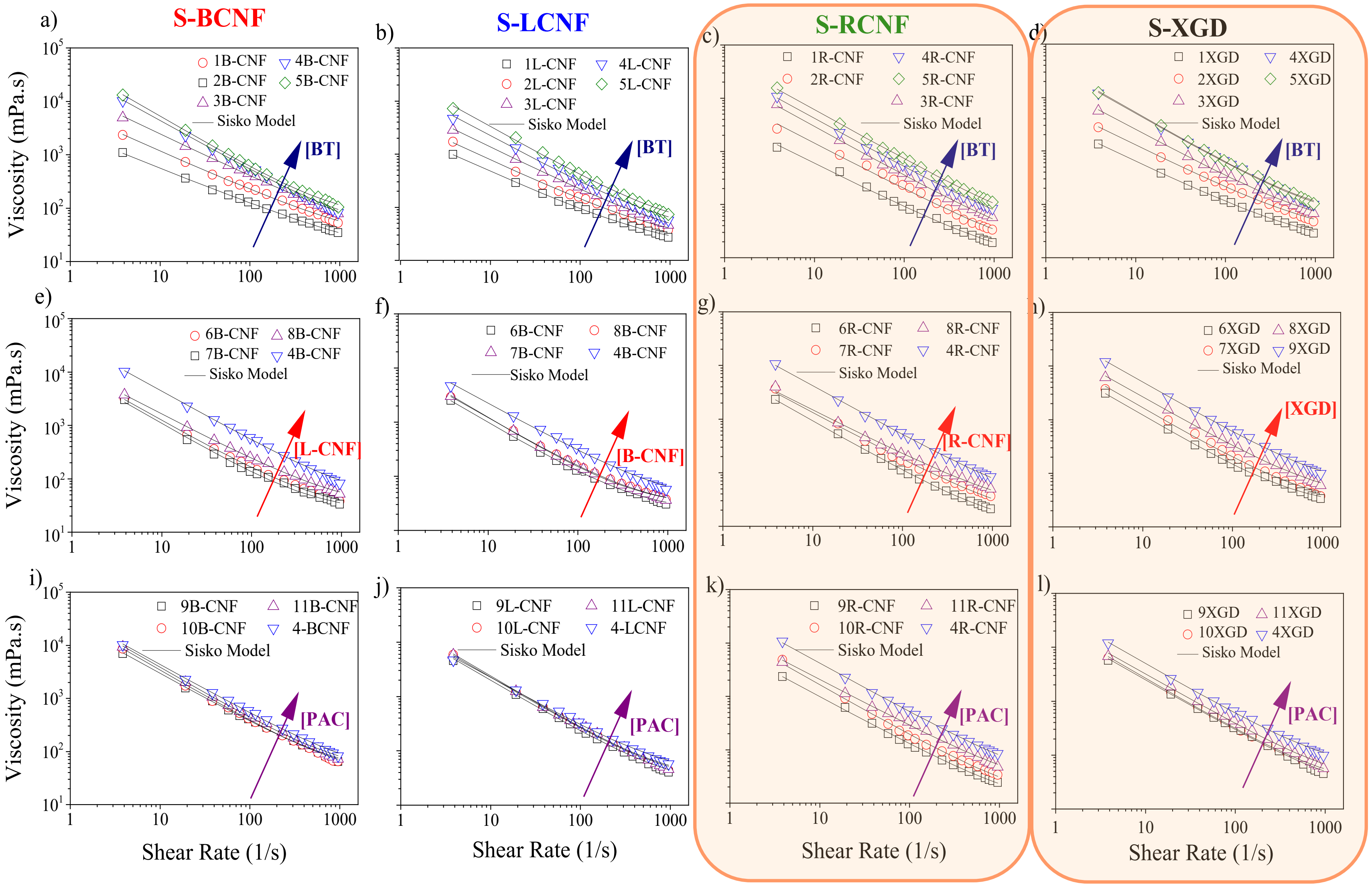
System S-RCNF: BT/R-CNF/PAC/H_2O

Fluid	BT (% m/m)	R-CNF (% m/m)	PAC (% m/m)
1R-CNF	0.00	0.50	0.50
2R-CNF	1.00	0.50	0.50
3R-CNF	3.00	0.50	0.50
4R-CNF	4.50	0.50	0.50
5R-CNF	6.00	0.50	0.50
6R-CNF	4.50	0.00	0.50
7R-CNF	4.50	0.10	0.50
8R-CNF	4.50	0.25	0.50
9R-CNF	4.50	0.50	0 00
10R-CNF	4.5 0	0.50	0.10
11R-CNF	4.50	0.50	0.25

System S-XGD: BT/XGD/PAC/H_2O

Fluid	BT (% m/m)	XGD (% m/m)	PAC (% m/m)
1XGD	0.00	0.50	0.50
2XGD	1.00	0.50	0.50
3XGD	3.00	0.50	0.50
4XGD	4.50	0.50	0.50
5XGD	6.00	0.50	0.50
6XGD	4.50	0.00	0.50
7XGD	4.50	0.10	0.50
8XGD	4.50	0.25	0.50
9XGD	4.50	0.50	0 00
10XGD	4.50	0.50	0.10
11XGD	4.50	0.50	0.25

Rheological Properties

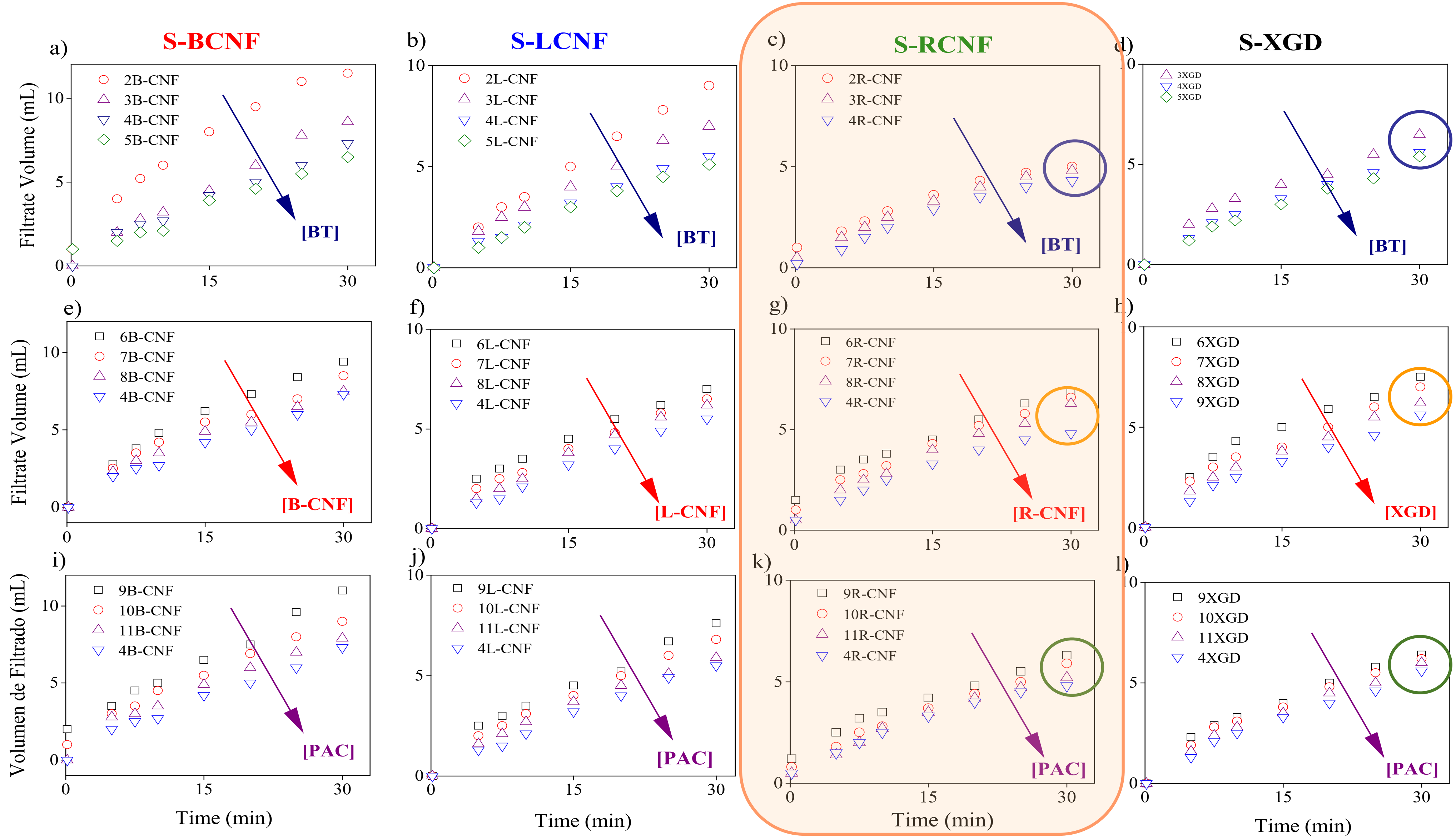


- ✓ A higher viscosifier effect of **R-CNF**
- ✓ Similar rheological behavior for **SR-CNF** and **S-XGD** systems

Sisko Model

$$\eta = \eta_{\infty} + k\dot{\gamma}^{n-1}$$

Filtration Properties

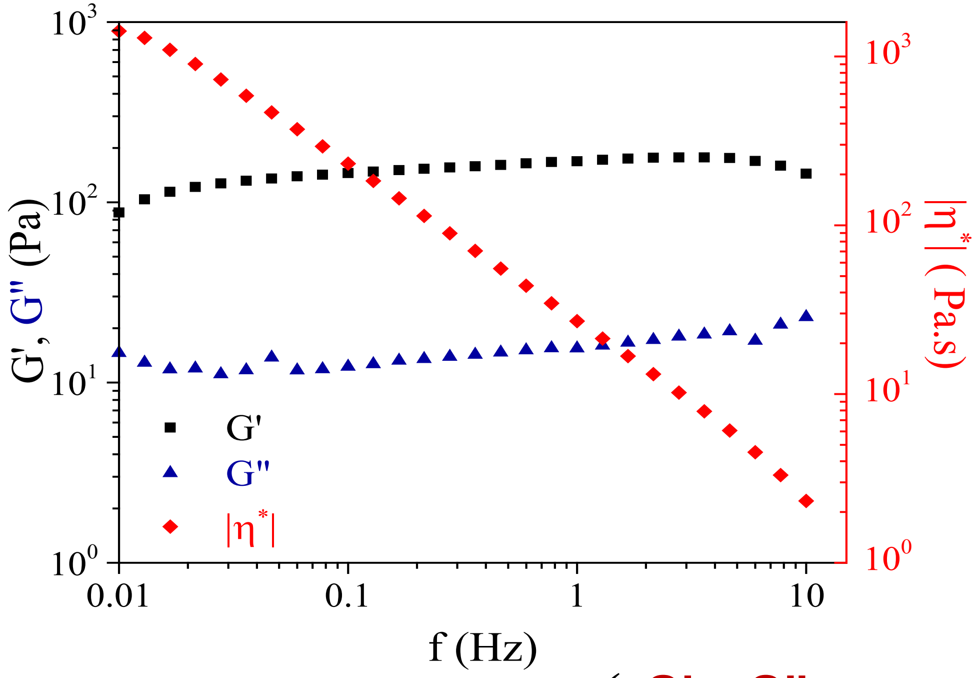


✓ Lower filtrate volume for **S-RCNF**

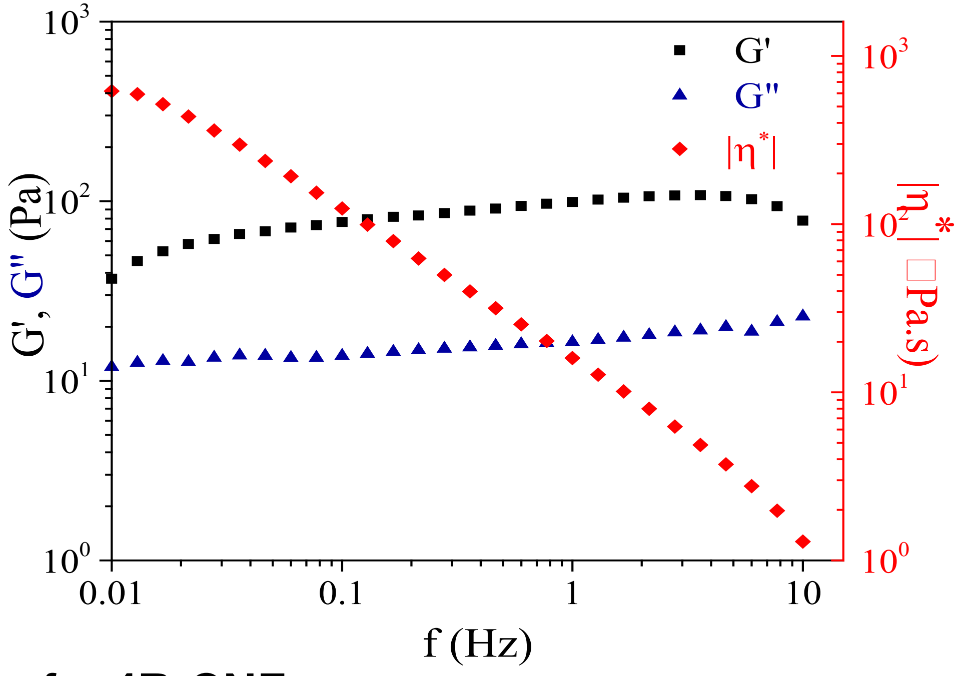
Viscoleastic Behavior

- ❑ Oscillatory-shear rheological properties

❑ 4R-CNF



❑ 4-XGD

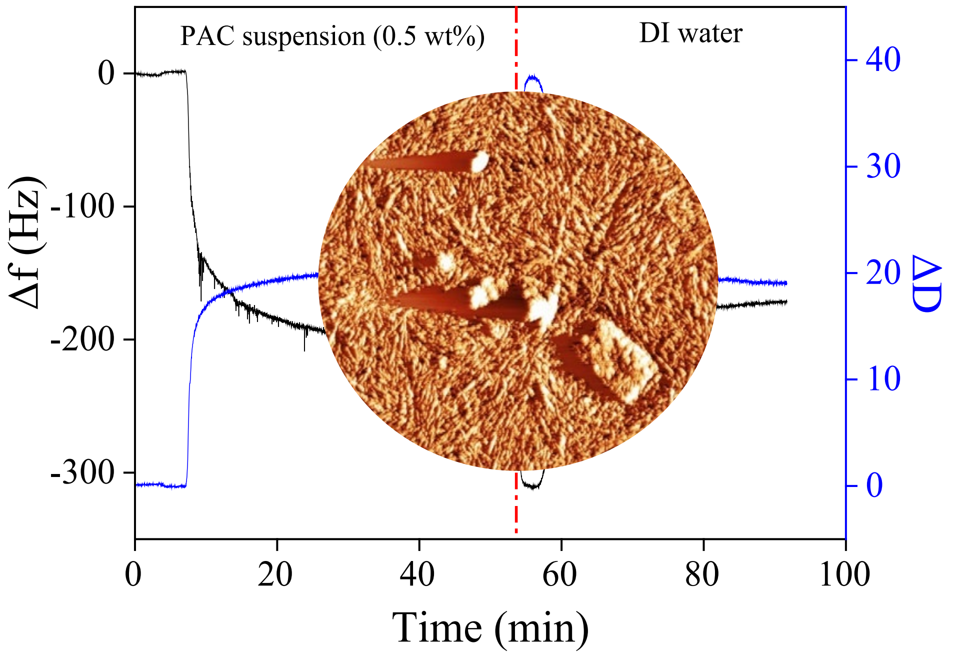


- ✓ **G' > G"** more noticeable for **4R-CNF**
- ✓ Stable structures
- ✓ Viscoelastic behavior
- ✓ Shear-thinning behavior

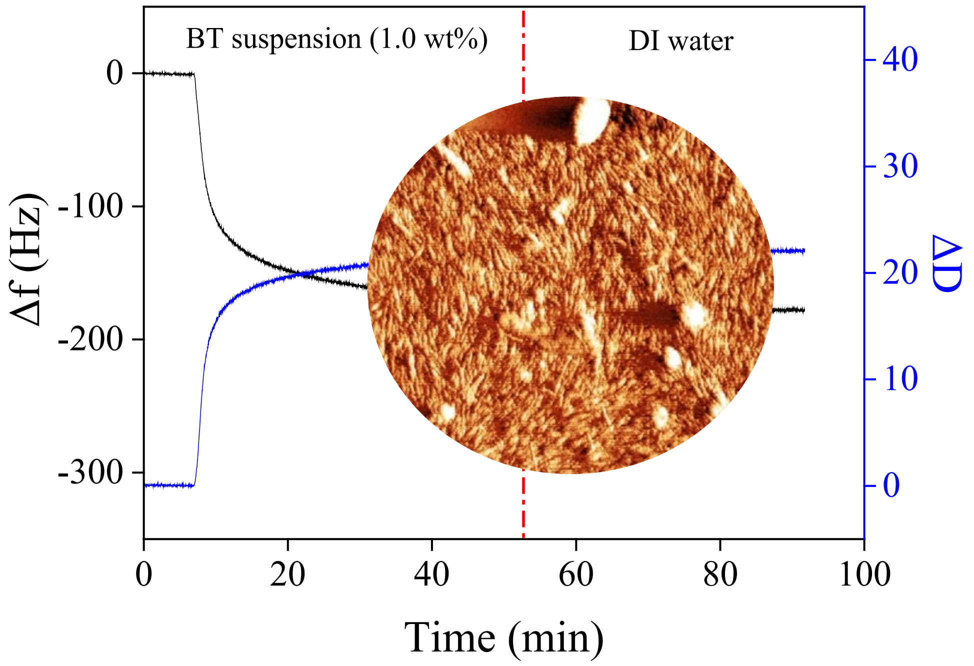
Surface Interactions

- ❑ QCM-D analyses

❑ PAC/R-CNF



❑ BT/R-CNF

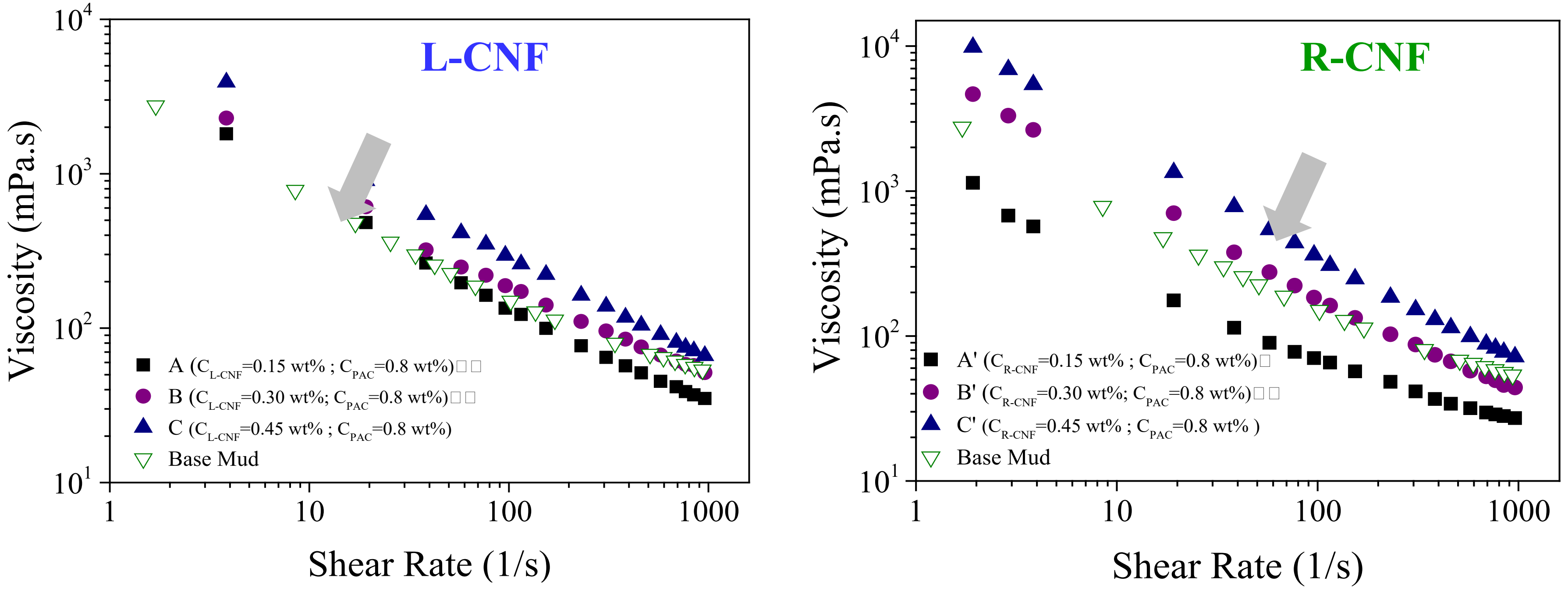


- ✓ Higher interaction with PAC
- ✓ Viscoelastic films (ΔD/Δf > 5%)

Replacement of XGD by R-CNF/L-CNF in WBMs for Argentina Shale

❑ Steady-shear rheological properties

Fluid	C_{XGD} (wt%)	C_{PAC} (wt%)	$C_{L\text{-}CNF\ or\ R\text{-}CNF}$ (wt%)
Base Mud	0.15	0.80	—
A – A’	—	0.80	0.15
B – B’	—	0.80	0.30
C – C’	—	0.80	0.45

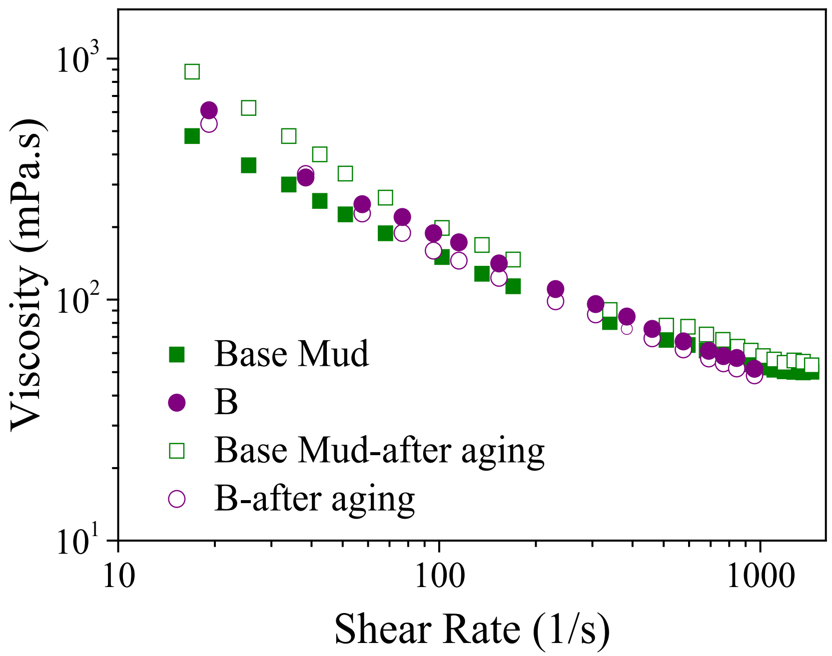


✓ Fluid with **$C_{L\text{-}CNF/R\text{-}CNF}$ = 2 C_{XGD}** (**Base Mud**) exhibited a similar rheological behavior

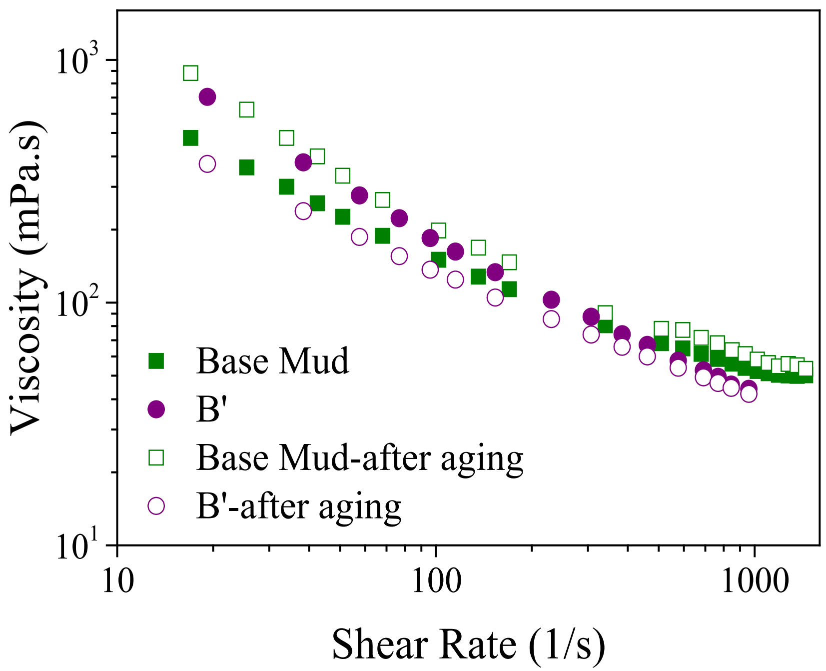
Thermal Properties

❑ Dynamic aging test

❑ **L-CNF**



❑ **R-CNF**



✓ Fluids with **L-CNF and R-CNF** (B and B’) exhibited better thermal stability

Structural Characteristics

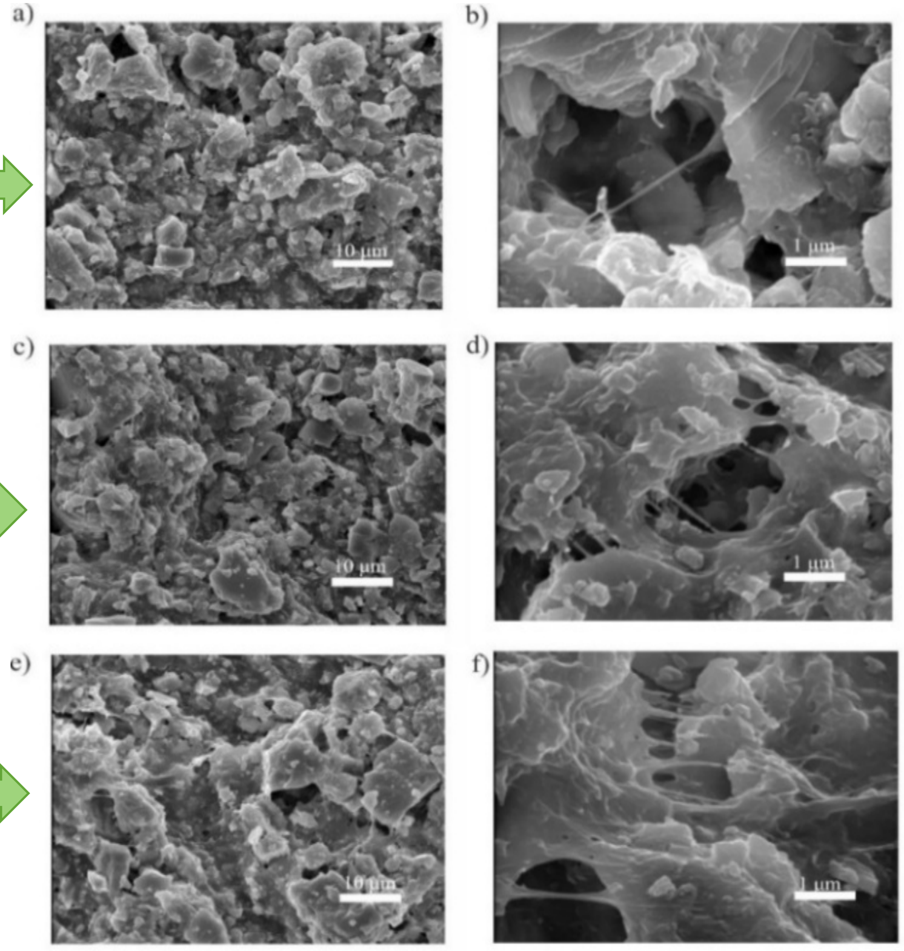
❑ SEM

WBMs with L-CNF

Fluid A

Fluid B

Fluid C

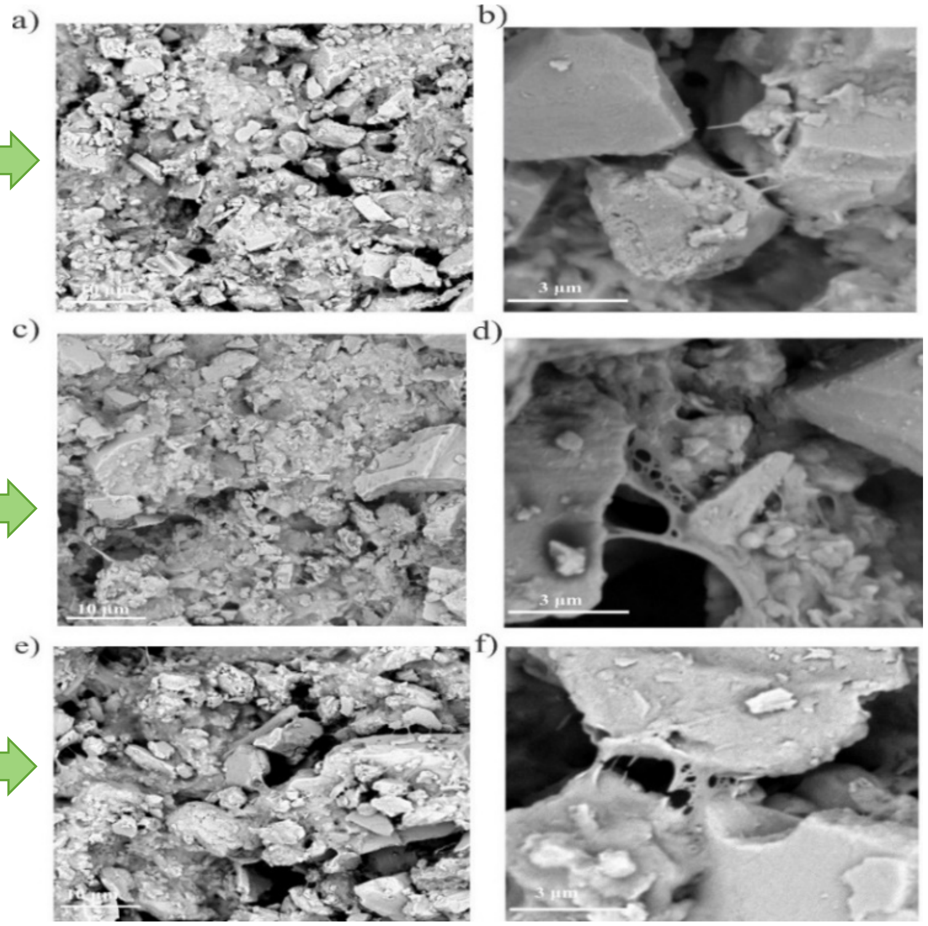


WBMs with R-CNF

Fluid A’

Fluid B’

Fluid C’



$C_{R\text{-}CNF}$

✓ Film formation
✓ Particles agglomeration

Conclusions

- ❑ The differences in surface characteristics, particle sizes, structures, lignin contents and functionalization of the CNFs significantly affected the functional properties of the WBMs.

- ❑ **For simple WBMs**

i) Pseudoplastic behavior and similar viscosities.

ii) Lower filtrate volumes for WBMs containing R-CNF

iii) Similar thicknesses of the filter cakes.

iv) Lower filtration rates and permeabilities for WBMs containing R-CNF.

- ❑ The results obtained by QCM-D indicated higher interaction between PAC and R-CNF.

- ❑ The fluids studied followed the rheological model of Sisko.

Conclusions

- For **specific WBMs:**

i) Rheological behavior very similar respect to the traditional fluid containing XGD with the double concentration of L-CNF and R-CNF.

ii) Higher thermal stability for WBMs containing R-CNF and L-CNF.

iii) Film formation and higher particle agglomeration with increasing concentration of L-CNF and R-CNF.

iv) Lower filtrate volumes for the fluid with R-CNF

- The use of CNFs as additives in WBMs is a promising alternative for the efficient design of WBMs for shale formations of Vaca Muerta.
- The L-CNF and the R-CNF presented advantages related to the performance of fluids and the potential economic and environmental benefits.

Acknowledgements

Thanks to:

✓Dra Diana Estenoz and Dra Natalia Casis (INTEC)

✓Dra Soledad Peresin-School of Forestry and Wildlife Sciences, Auburn University (USA).

✓Celeste Iglesias, PhD Student.

¡THANK YOU FOR YOUR ATTENTION!

Publications

Cellulose
https://doi.org/10.1007/s10570-018-2081-z

CrossMark

ORIGINAL PAPER

Cellulose nanofibrils as a replacement for xanthan gum (XGD) in water based muds (WBMs) to be used in shale formations

Yurany Villada · María Celeste Iglesias · Natalia Casis · Eleonora Erdmann · María Soledad Peresin · Diana Estenoz

Applied Clay Science 149 (2017) 59–66

Contents lists available at ScienceDirect

Applied Clay Science

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Research paper

Functional characterization on colloidal suspensions containing xanthan gum (XGD) and polyanionic cellulose (PAC) used in drilling fluids for a shale formation

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