Steam Exploded Lignocellulose as Binders for Coal-fines Briquetting

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STELLENBOSCH
UNIVERSITY
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forward together
saam vorentoe
masiye phambili

L, van der Westhuizen
JF, Görgens

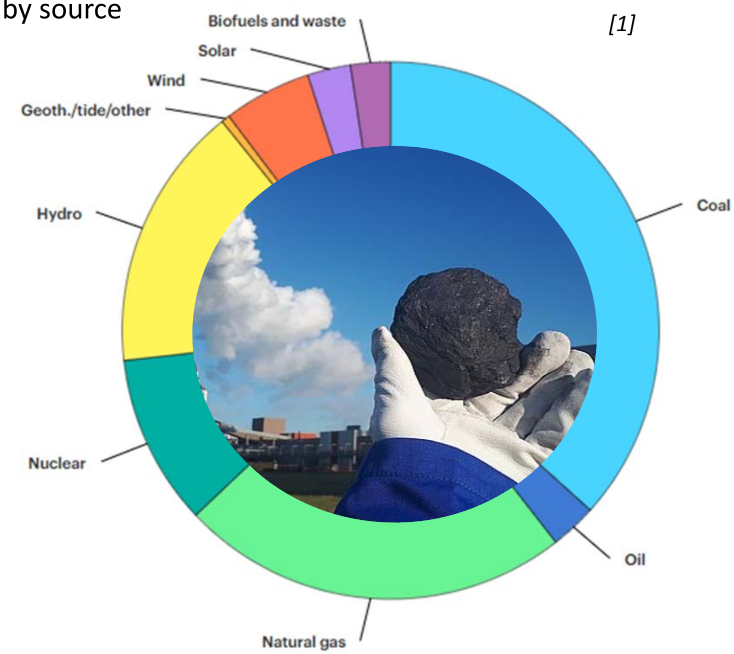
Department of Chemical Engineering
Stellenbosch University
South Africa

November 2023
Atlanta, GA

TAPPI
IBBC 2023 International Bioenergy & Bioproducts Conference

The other problem with coal

World electricity production by source



10%

[3]

Over 30 billion tons coal-fines deposited globally[2]	
Country	Fines deposits (Million tons)
China	9,500
India	4,500
United states	3,000
Indonesia	2,500
South Africa	2,400

Potential for briquetting and thermochemical conversion

Undesirable properties

- High moisture content
- Low density
- Low calorific value
- Difficult handling
- Dust formation

[6,7]

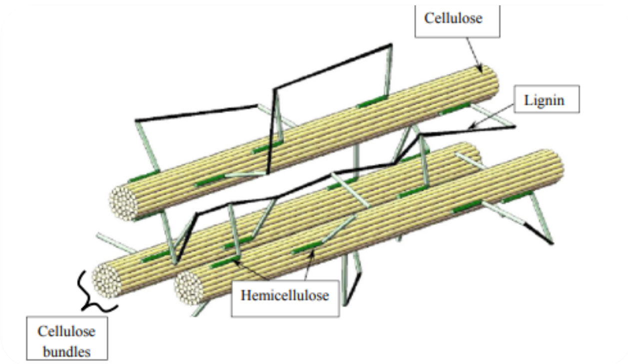
Binders are a major problem

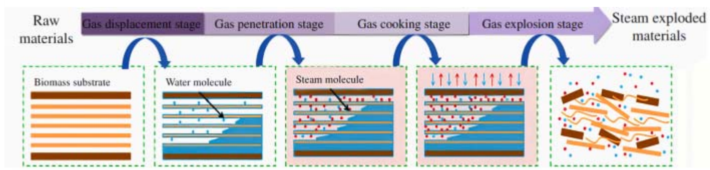
❖Coal briquettes: 50% of the cost[4]
❖Biomass pellets: $5-20/ ton[5]

Pelletizing/briquetting

- Increased energy density
- More uniform fuel
- Improved handling
- Higher market value

Lignocellulose as the binder





[8, 9]

Solubilizes hemicellulose

Alters and mobilizes lignin

Changes particle size/morphology

- Natural binders locked up in lignocellulose matrix
- Steam explosion (SE) to liberate these binders
- Improves:
  - Binding performance
  - Hydrophobicity
  - Energy density

Valmet black pellets [10]

Aims and Objectives

Investigate the application of steam exploded lignocellulose as a binder and fuel in coal-biomass briquettes

- Determine the process requirements in terms of:
  - Steam explosion process parameters
  - Suitability of different lignocellulosic sources
- Investigate the physical mechanism responsible for the enhanced binding

Lignocellulose feedstocks

Lignocellulosic biomass

Agricultural residues/Grassy lignocellulose

Woody lignocellulose

Hardwoods

Softwood

Corn stover (CS)

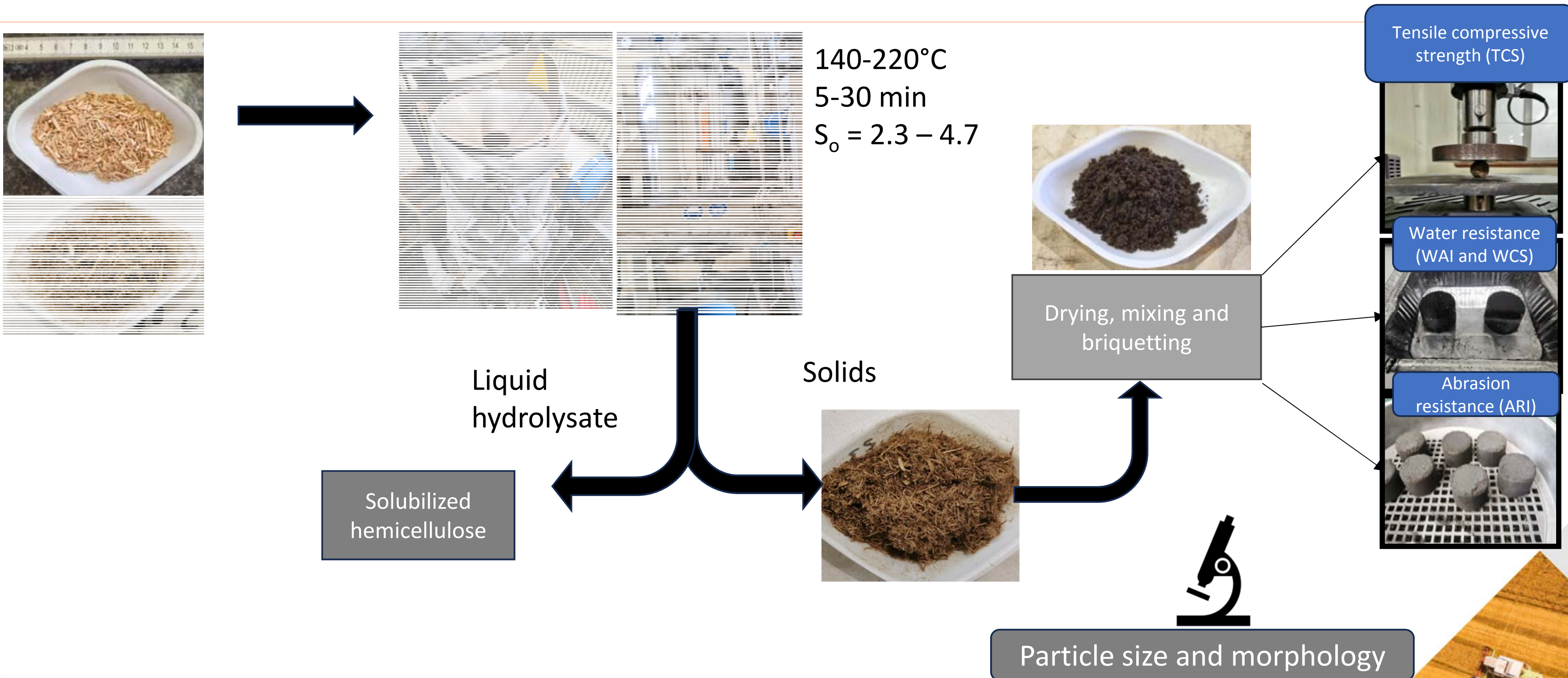
Sugarcane (SCB)

Eucalyptus (Euc) (*globulus)*

Black wattle (BW) (Acacia *mearnsii)*

South African Pine (Pinus *pinaster)*

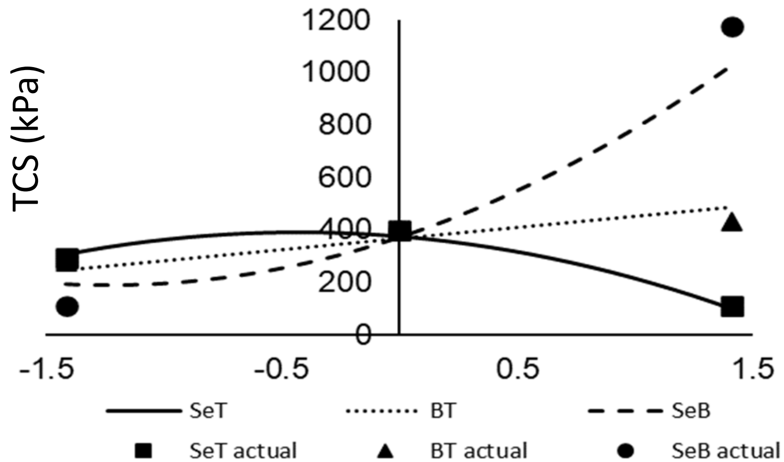
Experimental overview



Range finding experiments with sugarcane bagasse (SCB)

	TCS (kPa)
Untreated	-
140°C 15 min	-
140°C 30 min	-
180°C 15 min	120
180°C 30 min	142
220°C 5 min	65
220°C 15 min	45

10% SCB
Binderless: 49 kPa
Target: 350-1400 kPa

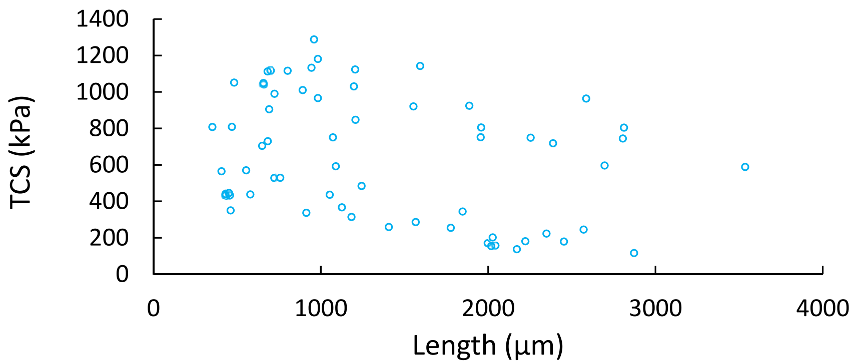


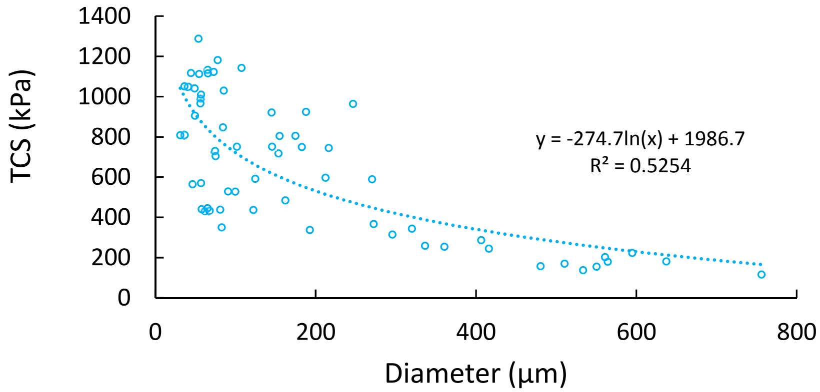
Central composite experimental design to evaluate:

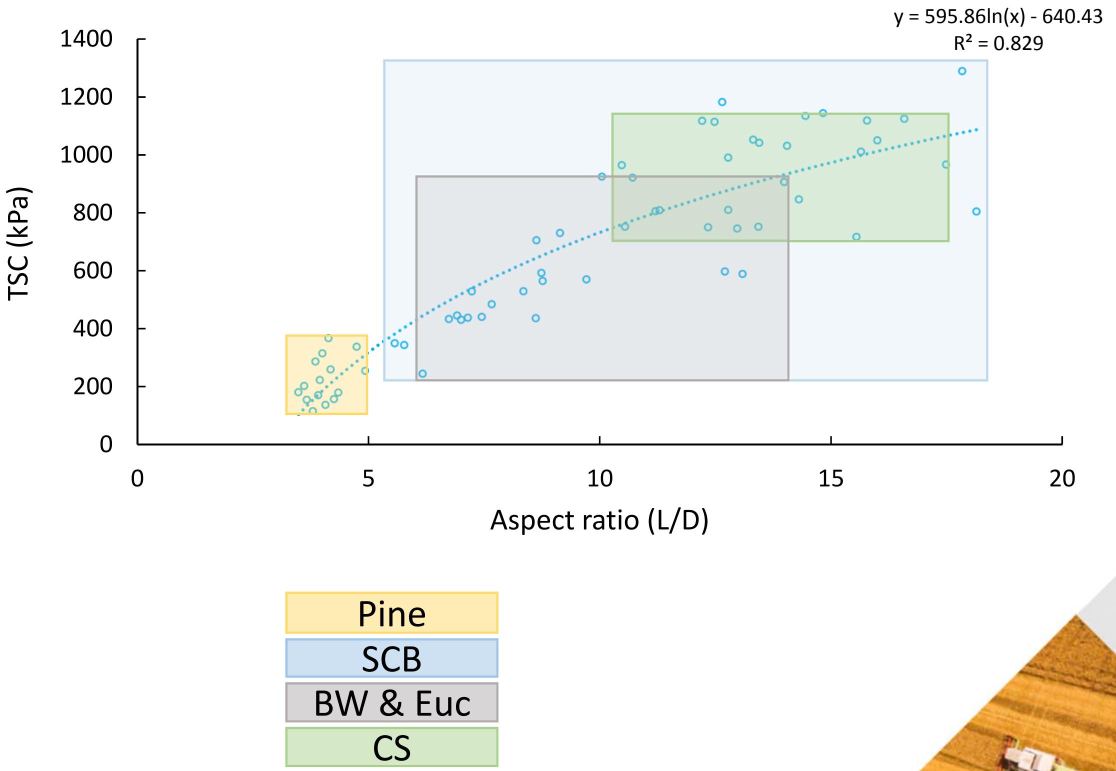
- steam explosion temperature (SeT)
- briquetting temperature (BT)
- steam exploded biomass content (SeB)

SeT (°C)	BT (°C)	SeB (%)	TCS (kPa)	ARI (%)	WAI (%)	WCS (kPa)
190	100	17.8	1205	97	82	501
Targets			350-1400	85	80	350-1400

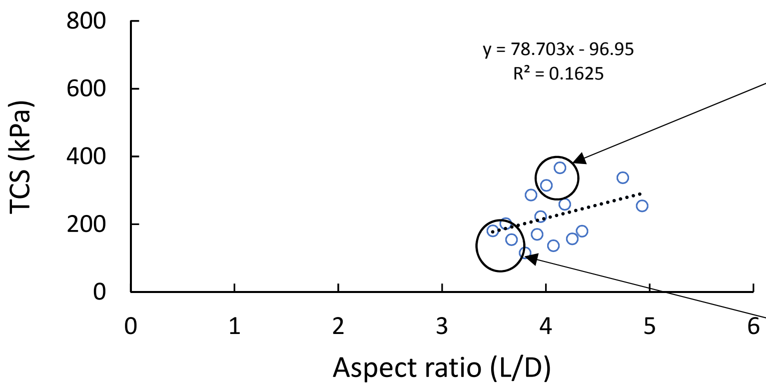
Relationship between steam exploded lignocellulose particle properties and tensile compressive strength

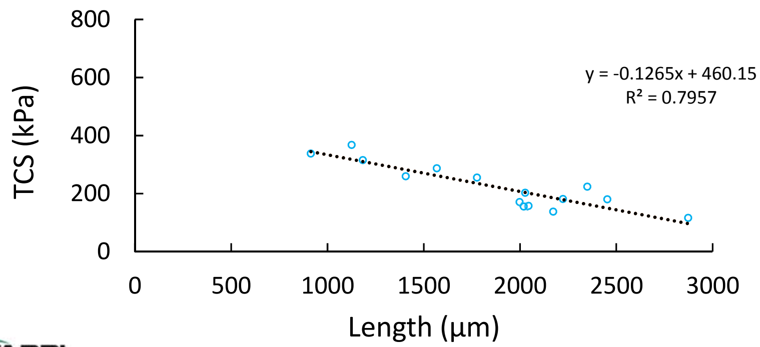


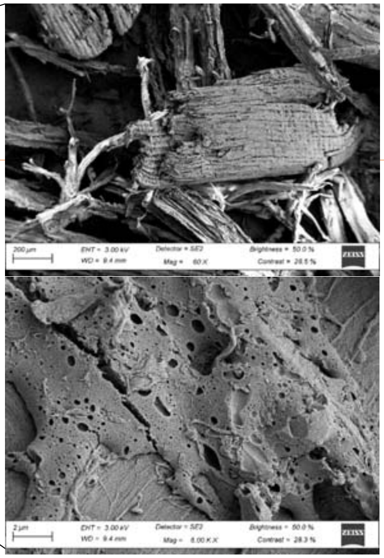




Pine

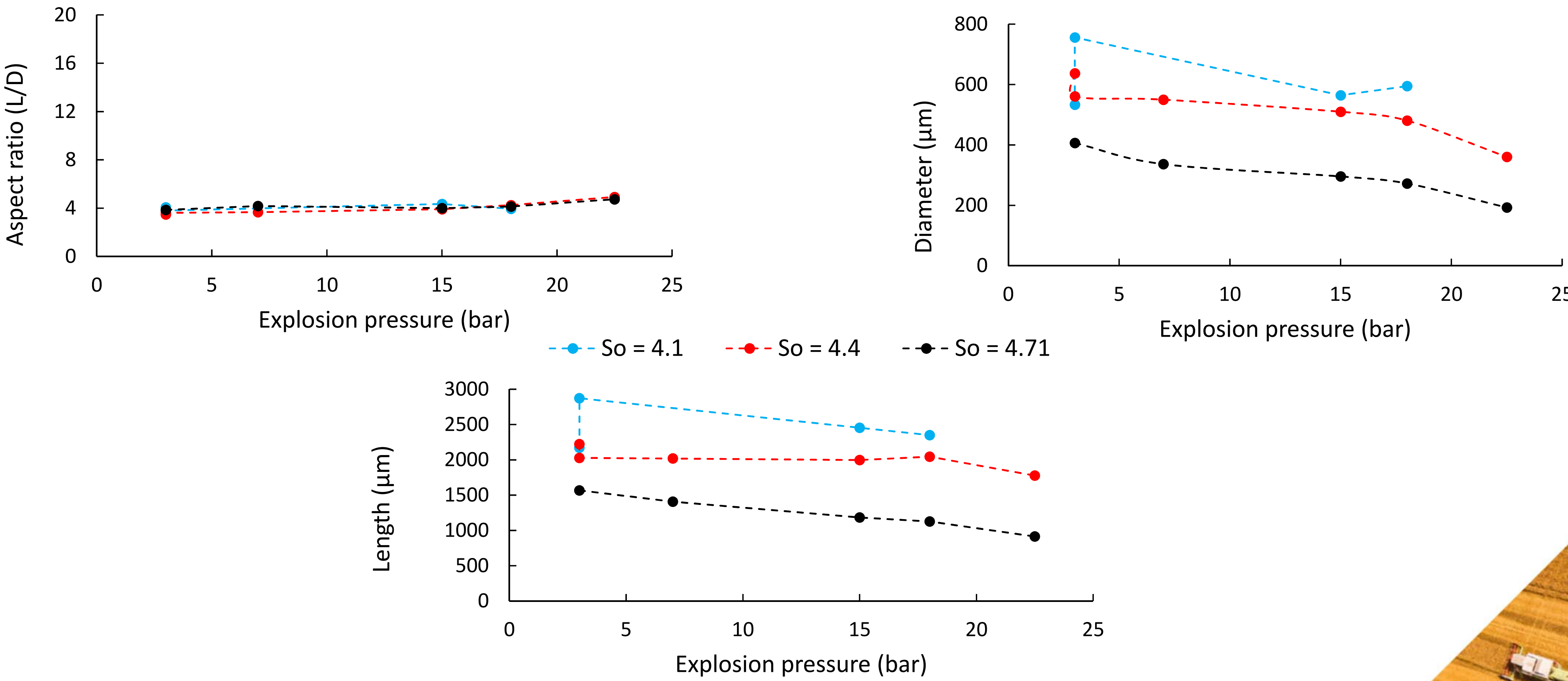






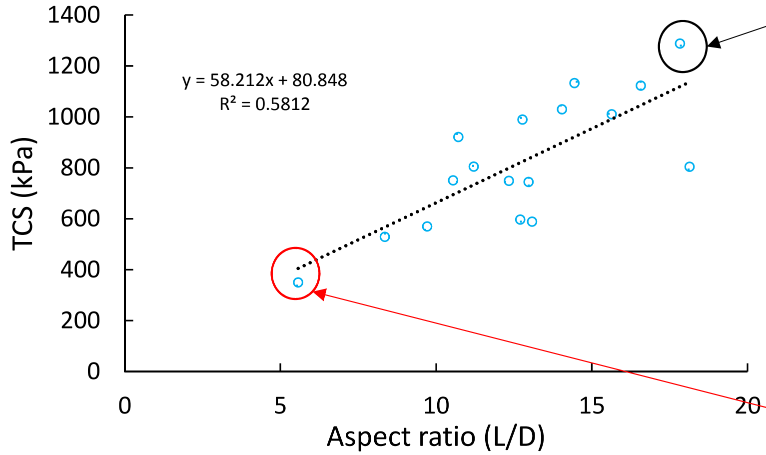
Particle length & diameter negative linear relationship with TCS

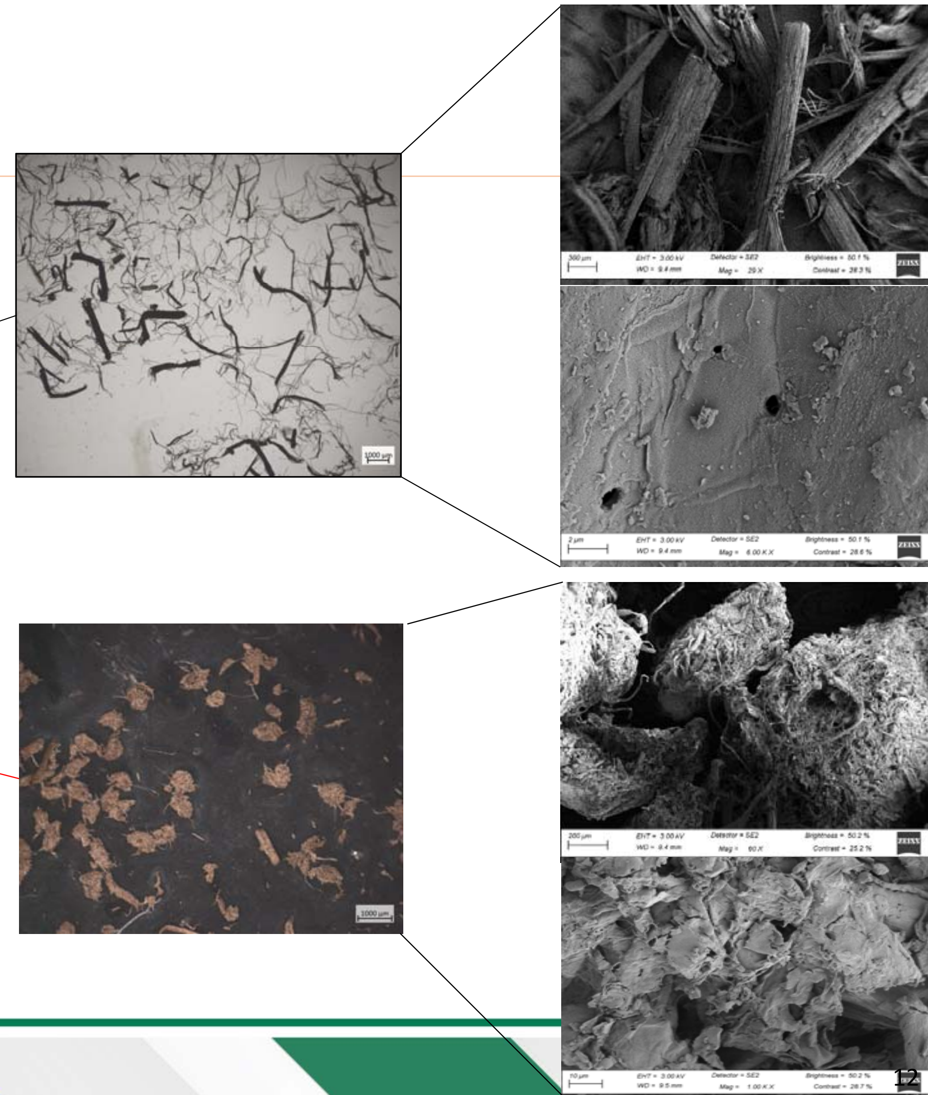
Pine



Aspect ratio (L/D)
20
16
12
8
4
0
0
5
10
15
20
25
Explosion pressure (bar)
Diameter (µm)
800
600
400
200
0
0
5
10
15
20
25
Explosion pressure (bar)
So = 4.1
So = 4.4
So = 4.71
Length (µm)
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
Explosion pressure (bar)

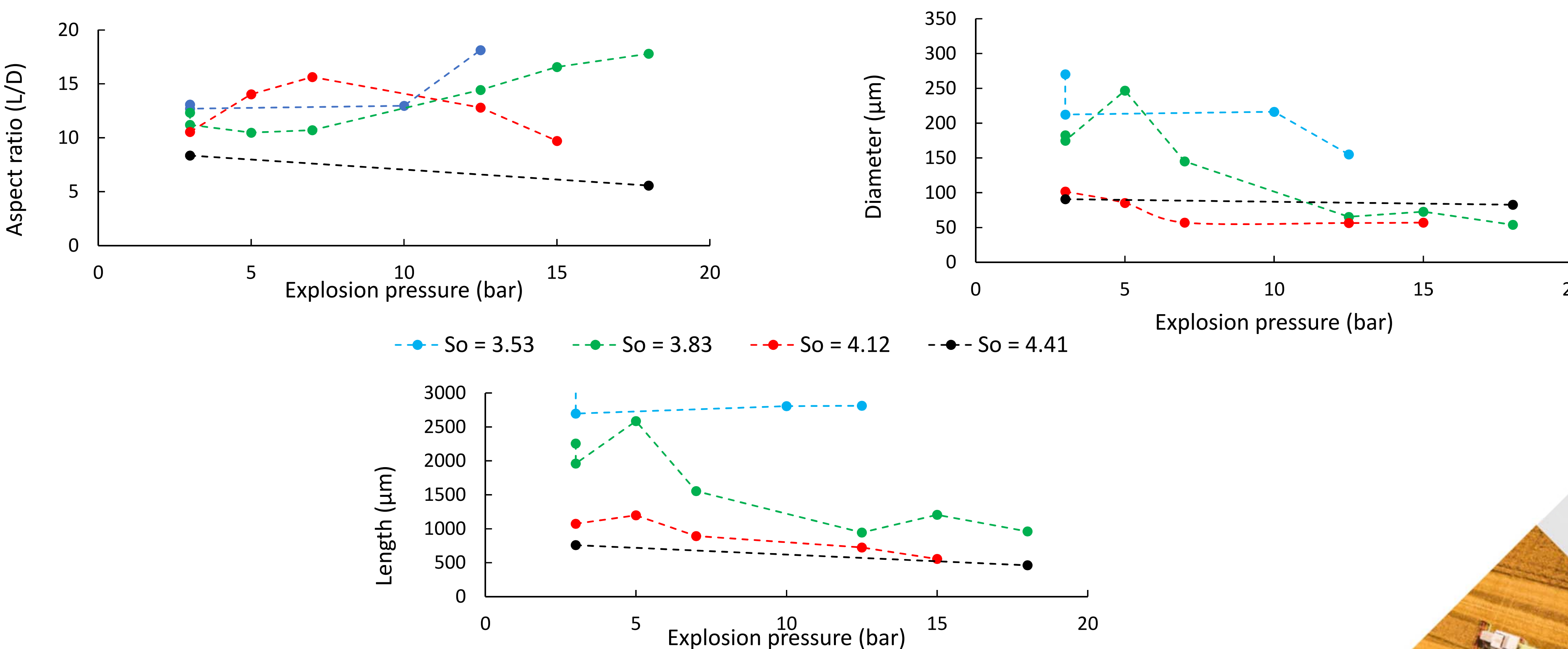
Sugarcane bagasse



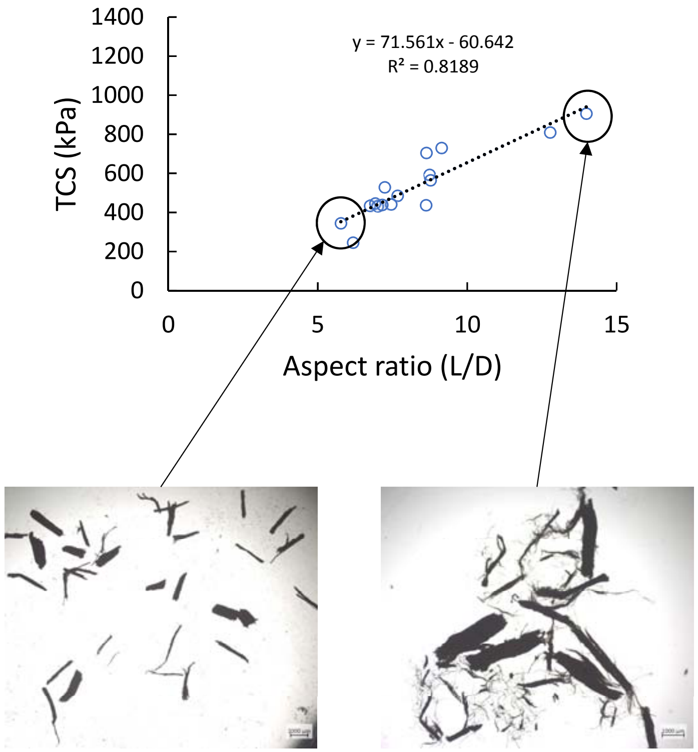


No correlation found between length or diameter and TCS

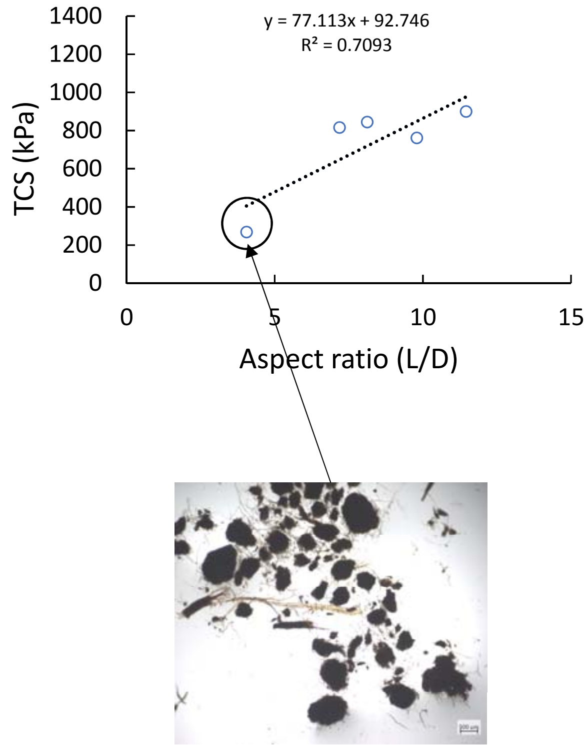
Sugarcane bagasse



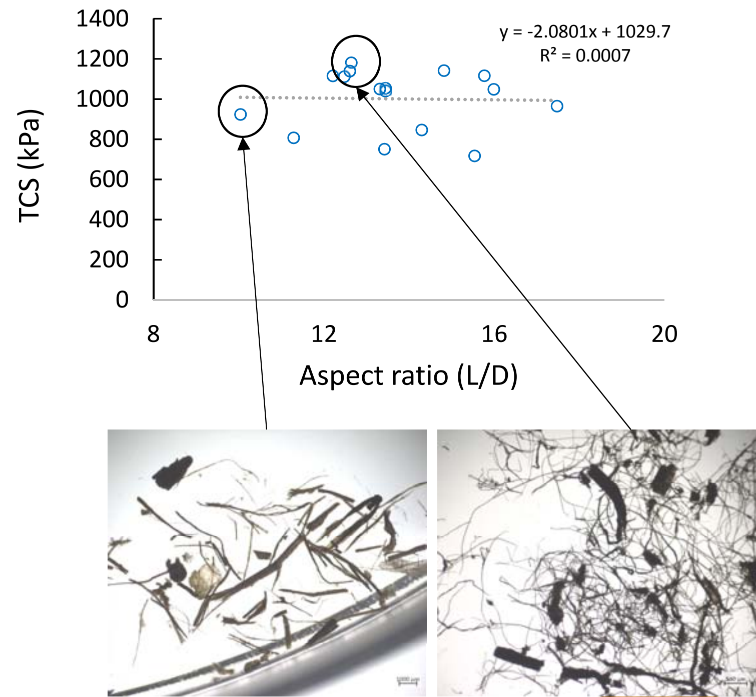
Black wattle



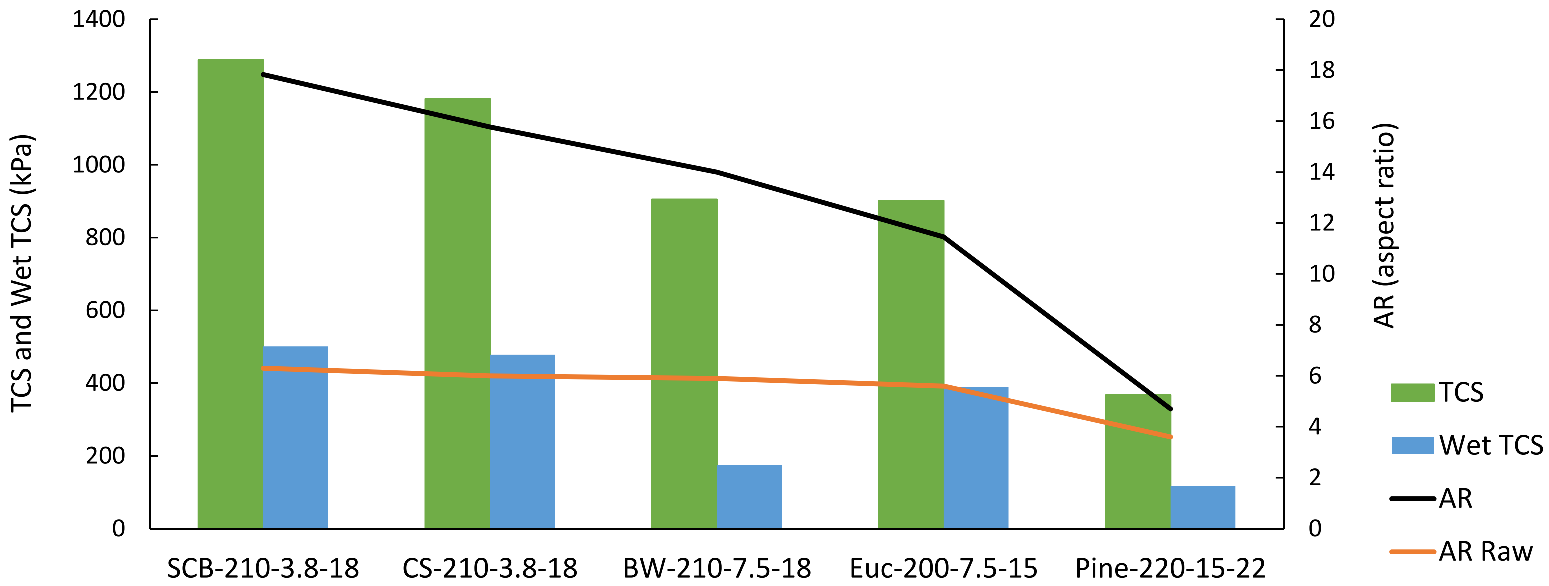
eucalyptus

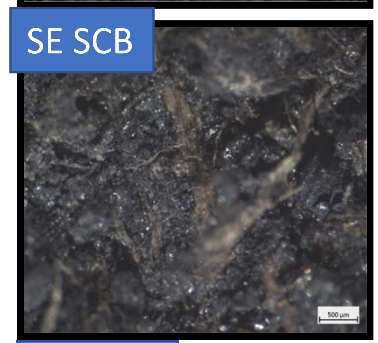


corn stover

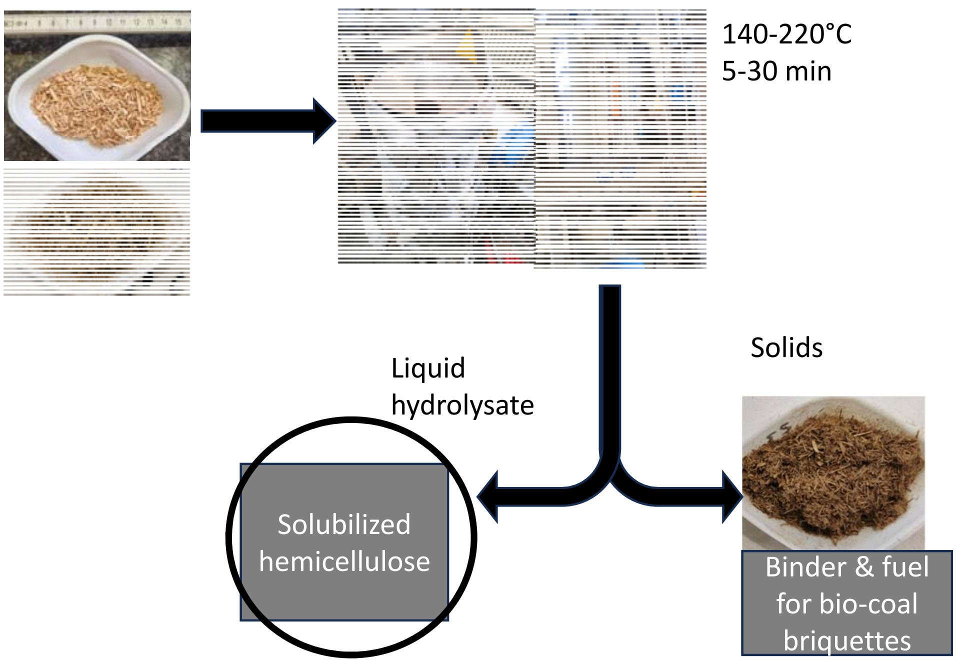


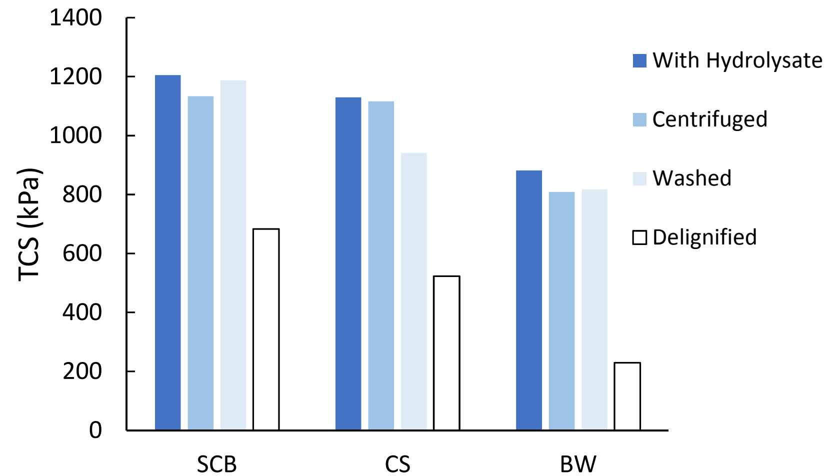
Summary of the physical binding mechanism and water resistance





Application in bio-refinery context





Next steps:
- Simultaneous optimization of oligosaccharide yield and binder performance
- Techno-economics

Conclusion

- Lignocellulose type have a significant impact on binding performance

  Agricultural residues > hardwoods > softwoods

- Aspect ratios are a good indication of binding strength

- Optimal treatment conditions are those that increase particle aspect ratio

- Beyond certain AR, binding strength does not increase

- Solubilized carbohydrates have negligible impact on briquette strength

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