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Comminution process on wet lignocellulosic biomass powders: application to biofuels development

Mathis Thouret¹, Komlanvi Lampoh¹, Vincent Richefeu², Jean-Yves Delenne¹, Claire Mayer-Laigle¹

Bioressources & bioéconomie :
Valorisation, sobriété, circularité

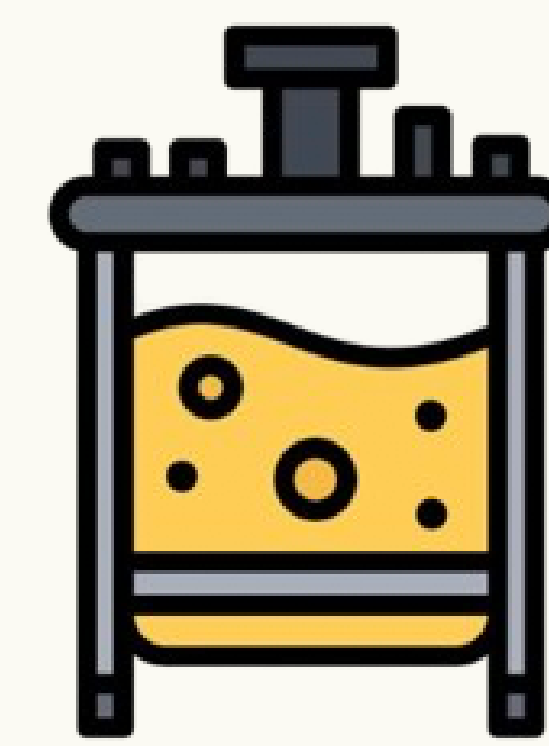
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General context

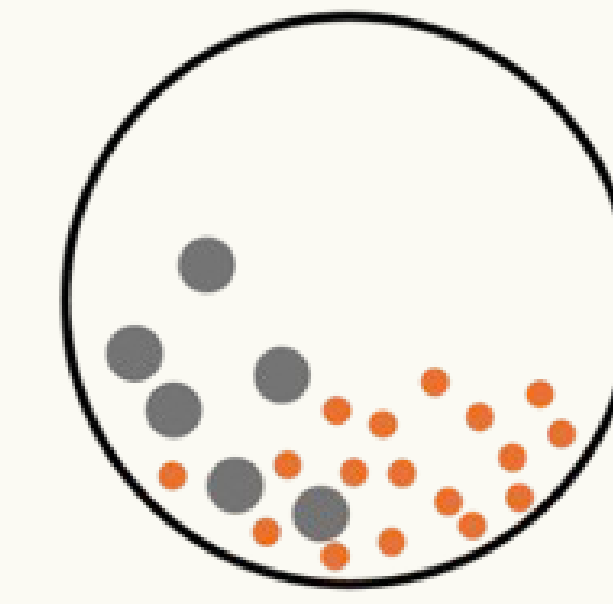
The world is facing significant population growth as well as a massive depletion of fossil resources. To address this shortage affecting many sectors, such as transportation, new forms of energy are emerging, including biofuels.

The development of second-generation biofuels relies on the conversion of sugars contained in lignocellulosic biomass into ethanol through fermentation. To improve sugar accessibility for enzymes, mechanical deconstruction can be introduced between fermentation steps. Since drying processes are both energy- and cost-intensive, feedstocks must be milled at their fermentation water content, where the system consists of air, water, and solid particles.

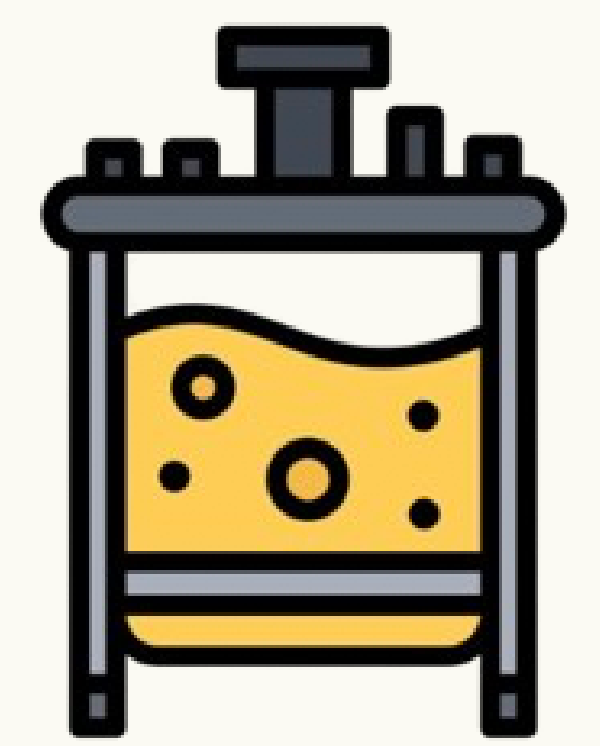
This poster presents a combined DEM-experimental methodology to investigate the milling of unsaturated biomass powders.



Fermentation



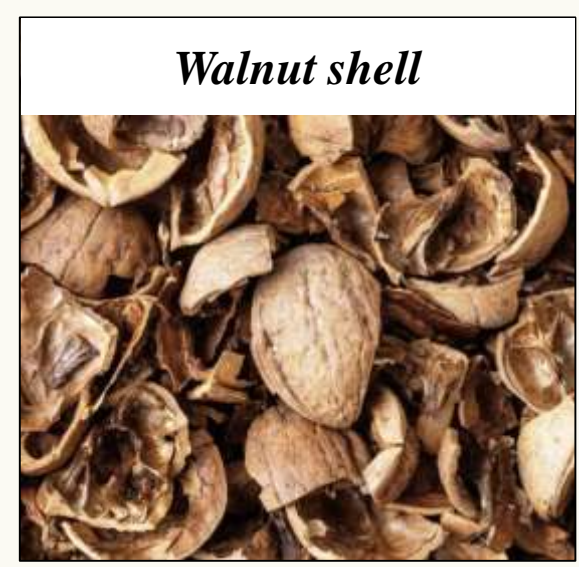
Milling



Fermentation

Co-treatment process for the development of second generation biofuels

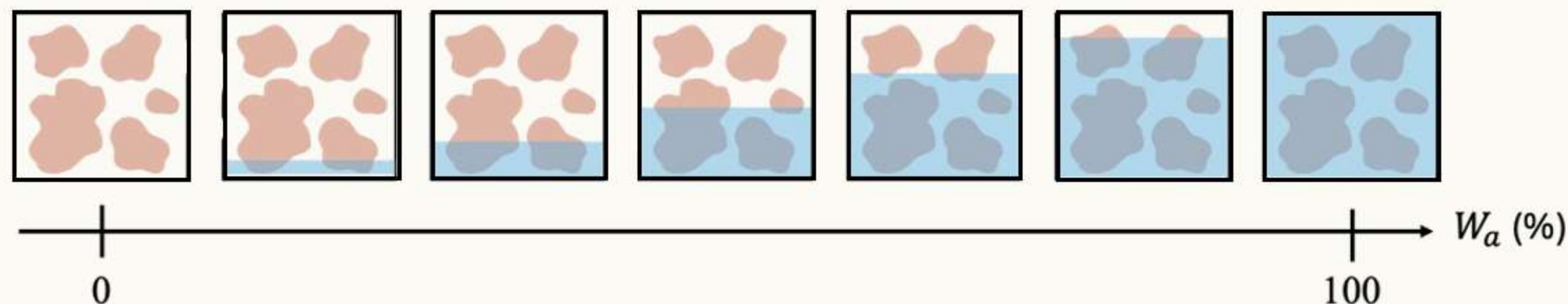
A benchmark of biomass powders



Each biomass is pre-ground using a knife mill to homogenize its particle size distribution (PSD).

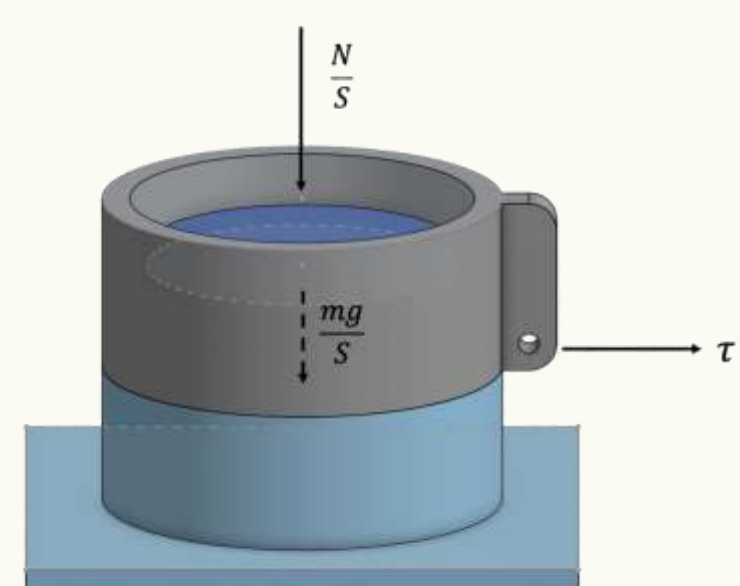
Impact of water on mechanical and flowability properties

Each biomass is prepared at different water contents, and two tests are performed: vibratory densification and direct shear tests.

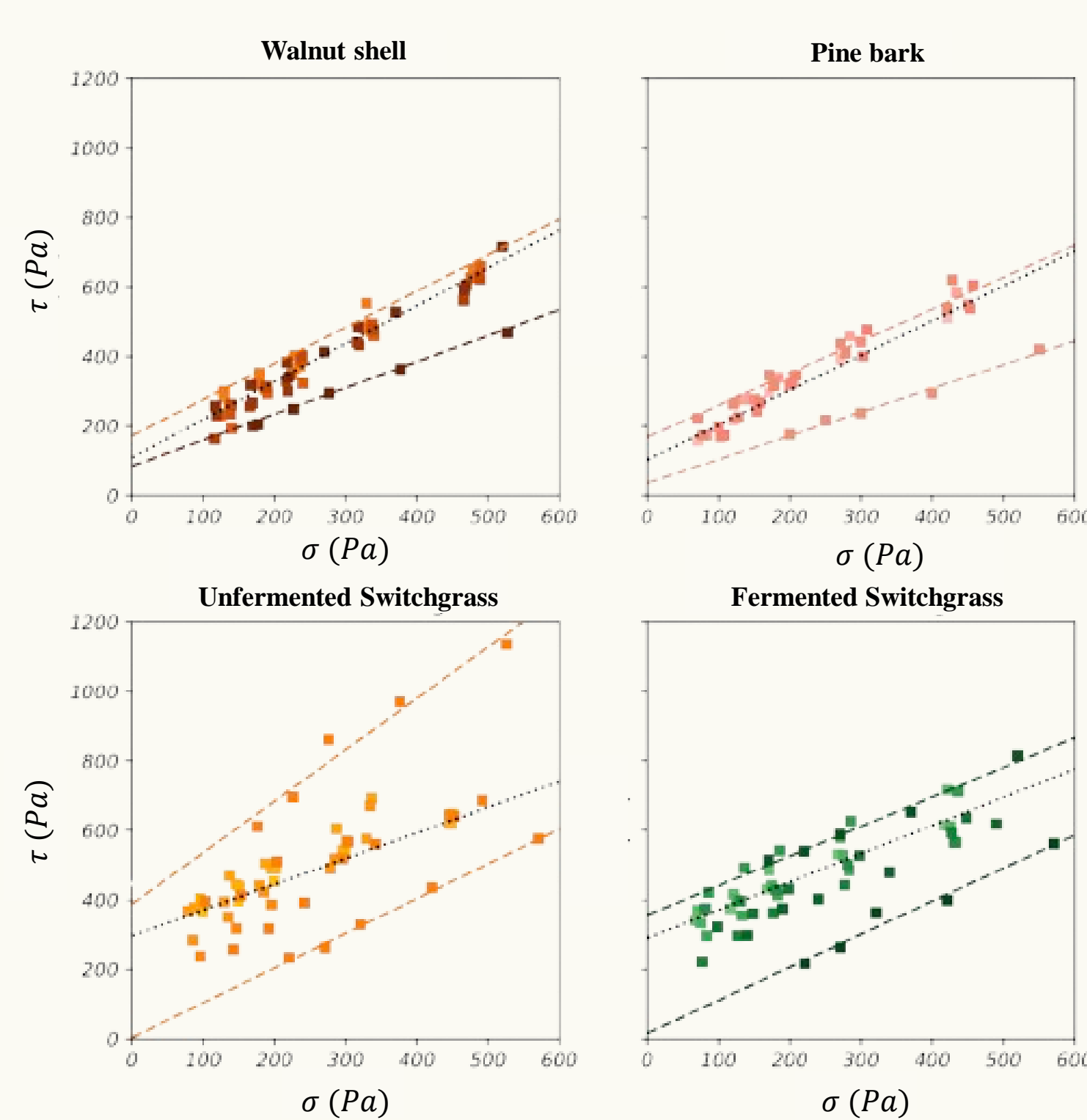


1 Cohesion measurement with direct shear tests

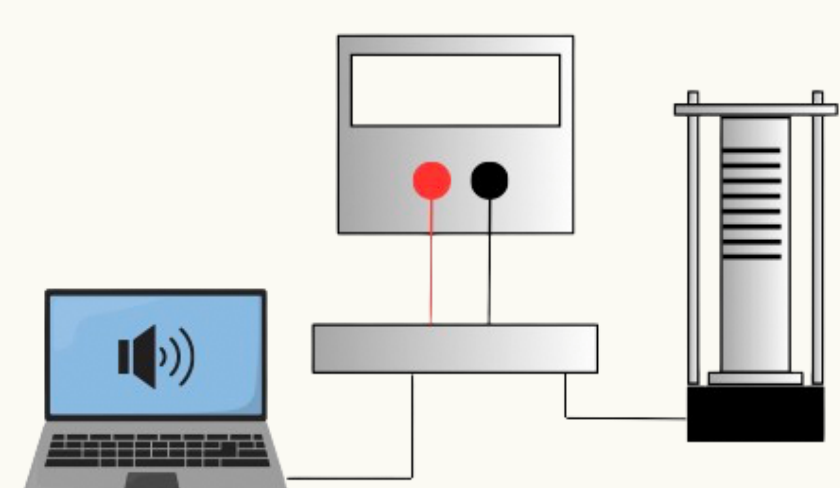
Mohr-Coulomb cohesion is measured using a Jenike cell made in house and the following equation: $\tau = \tan(\varphi) \cdot \sigma + C$



Experimental setup



2 Carr index measurements with vibratory densification tests

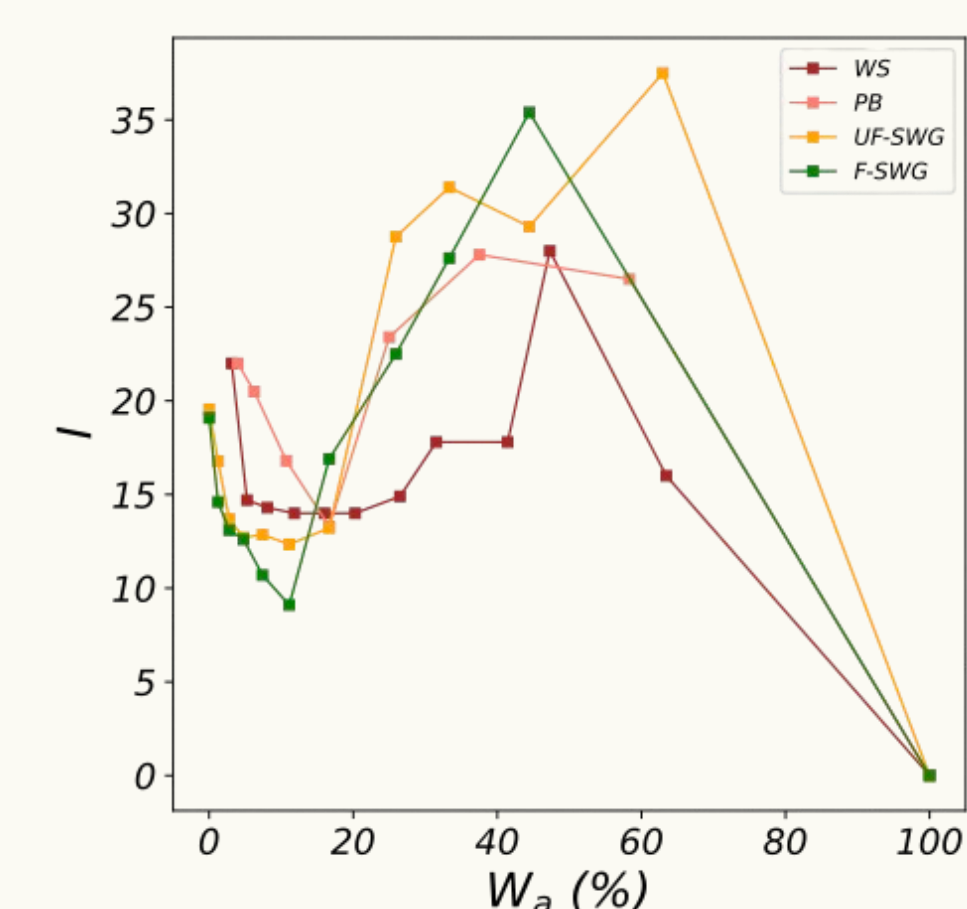


Experimental setup

$$I = \frac{V_i - V_f}{V_i} \cdot 100$$

V_i : initial volume

V_f : final volume

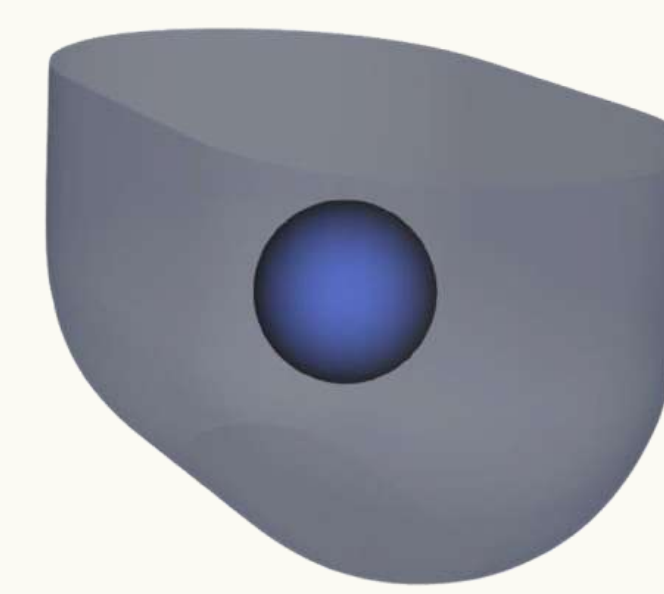


An optimum in densification have been observed for $W_a \approx 50\%$.

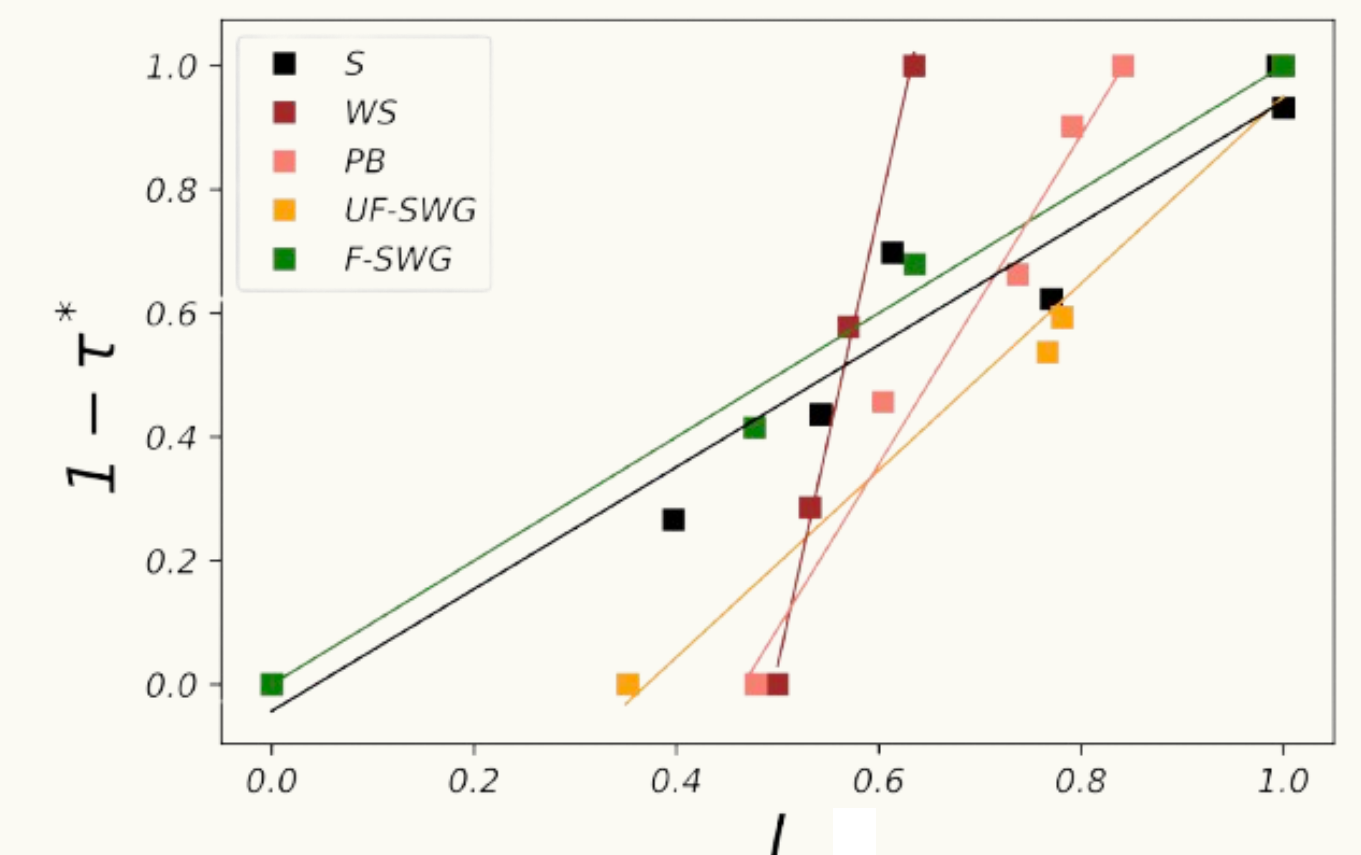
A laboratory-scale model for grinding efficiency under different mechanical solicitations

1 Impact solicitation

Each biomass was ground at different water contents using a vibratory ball mill with a single 20mm ball. The grinding rate of each sample (defined as the ratio between the creation of specific surface area and the grinding energy) was correlated with the Carr index measured with vibratory densification tests.



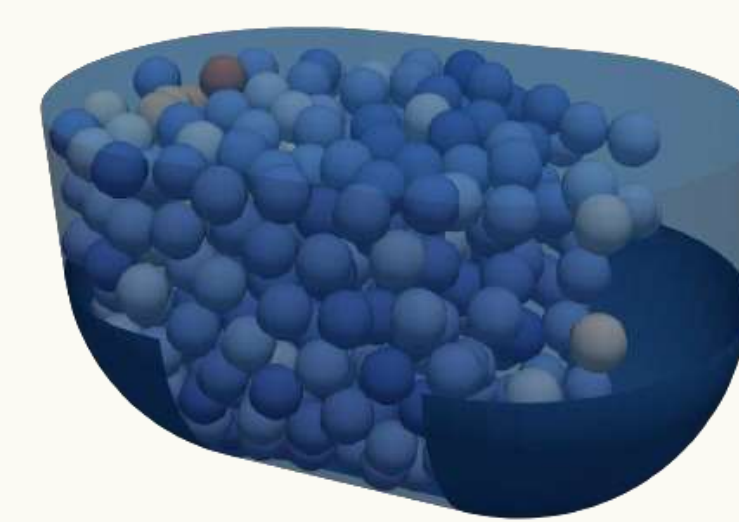
DEM model of the Lab scale vibratory ball mill with a single 20mm ball.



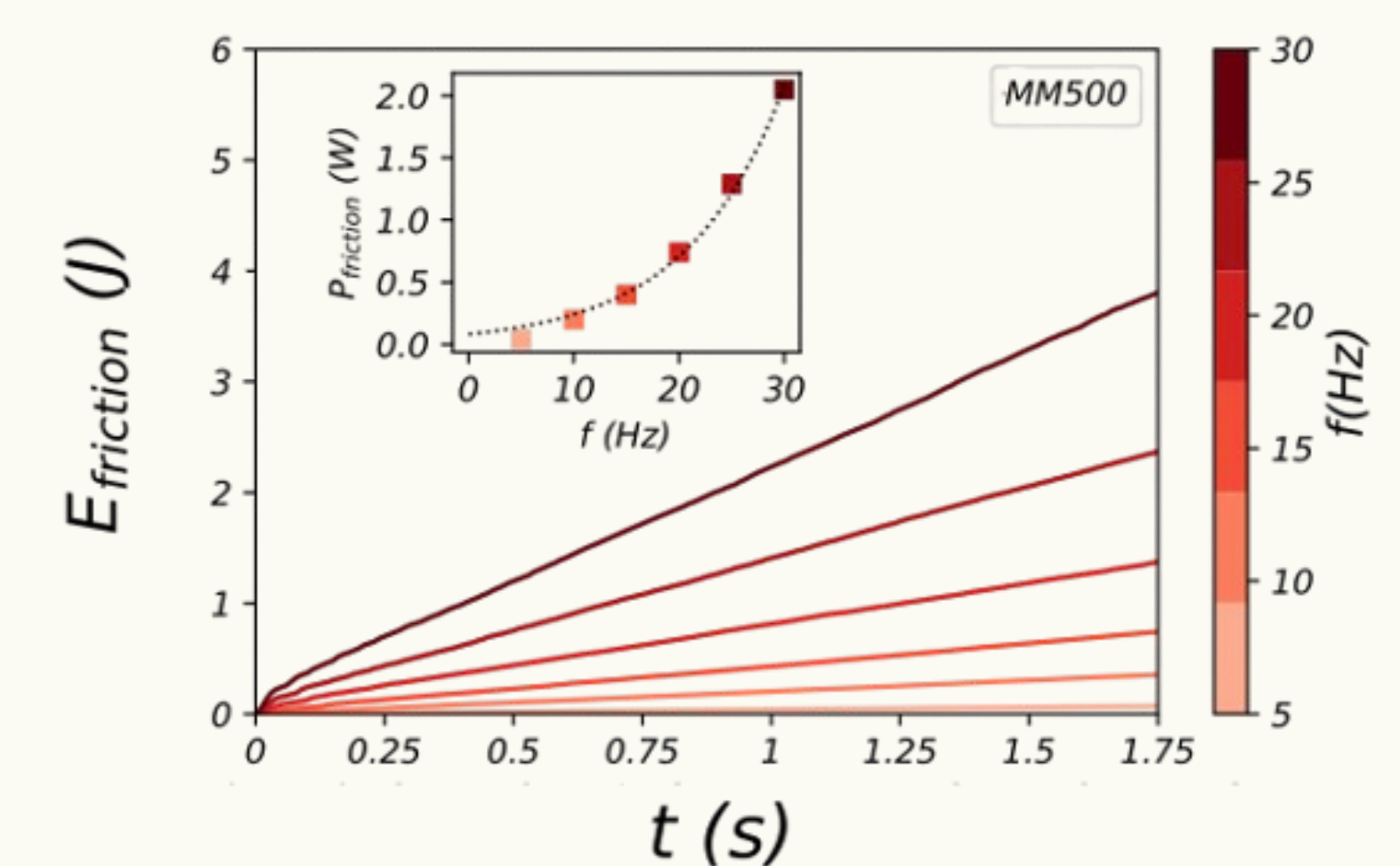
Normalized grinding rate as function of the normalized densification index

2 Attrition solicitation

Discrete elements method modelling

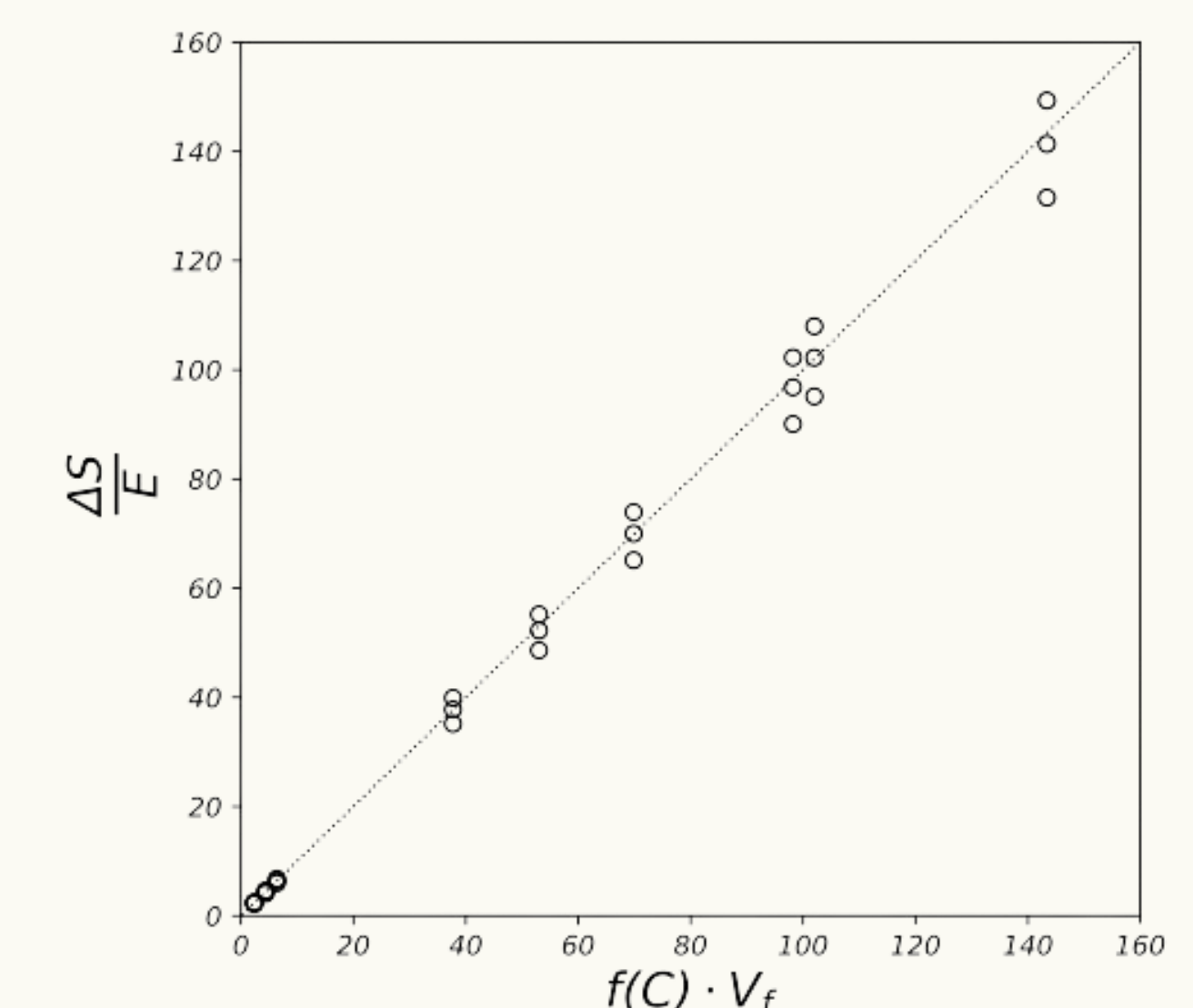


DEM model of the vibratory ball mill



Experimental approach

Switchgrass was ground with 6mm beads under three moisture levels (60%, 70%, 90%), three filling volumes (27%, 50%, 73%), and three bead-to-feedstock mass ratios (0.05, 0.06, 0.07). A relationship was observed between filling volume, feedstock cohesion, and grinding efficiency.



Conclusion

This bottom-up approach, starting from the fundamental mechanical and rheological properties of biomass powders, allows to provide a deeper understanding of the milling process under unsaturated water conditions. The densification and the cohesion of the media appear to be key indicators for explaining the grinding efficiency. Under impact mechanical loading, the grinding rate and densification are linearly correlated: the more cohesive the powder, the less efficient the grinding process. However, in the case of frictional loading, the effect of cohesion must be nuanced by the filling volume. A cohesive powder requires a higher filling volume to maximize contact between the grinding media and the powder.

Acknowledgements

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<https://doi.org/10.15454/1.5572338990609338E12>

References

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- Thouret et al., A comparison between lab-scale and pilot scale ball mill for the grinding of wet Switchgrass, ESCC 2026.