Agricultural waste extensive mechanical pretreatment at lab-scale before anaerobic digestion: An integral approach

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Laboratoire DEEP, Université de Lyon, INSA Lyon - France

R. Bayard, Helen Coarita Fernandez, P. Buffière

Corresponding author: remy.bayard@insa-lyon.fr

Anaerobic digestion / lignocellulosic biomass feedstocks : Challenges

- ❑ Clogging of valves, pipes and pumps
- ❑ Mixing problems
- ❑ Low or slow bioconversion to methane

Photo : Pacaud, S., Experimental Farm La Bouzule.

Why to use a pretreatment?

→ Eliminate unwanted elements
→ Increase biodegradability & bioconversion rate
→ Improve the homogenization
→ Guarantee the balance of the ration
→ Improve rheological properties
→ Reduce operation and maintenance costs (OPEX)

Mechanical pretreatments

In the agricultural sector, mechanical pretreatments are the most applied operations. There is a wide range of mechanical technologies (ball mills, disc mills, chain mills, etc.), the hammer and knife mill being the most used.

Hammer mills

Chain mills

*Disponible sur: https://www.verde-energy.fr/bio-preparateur-tqz/

Knife mills

- **Easy to use,**
- **No risk of inhibitors production and,**
- **Do not require the use of costly operations like rising the temperature or adding chemicals**

But…

Mechanical pretreatment

The evaluation of the efficiency of a mechanical pretreatment is a difficult task.

To our knowledge, there are still very few objective criteria enabling to qualify separately the different effects of mechanical pretreatments. Indeed, mechanical operations are a combination of size reduction, mixing and fiber breakdown.

Evaluate the physical and biochemical effects using successive mechanical pretreatments on different biomass feedstock at in situ & lab-scale

1- **Selection** of several sites with specific mechanical pretreatments / biomass
2- **Biomass sampling** before and after mechanical operation

- Pretreatment types
- Feedback
- Biomass
- Availalability

Site #1

✓ Mobile Hammer Mill (HM1)
✓ Cattle Manure

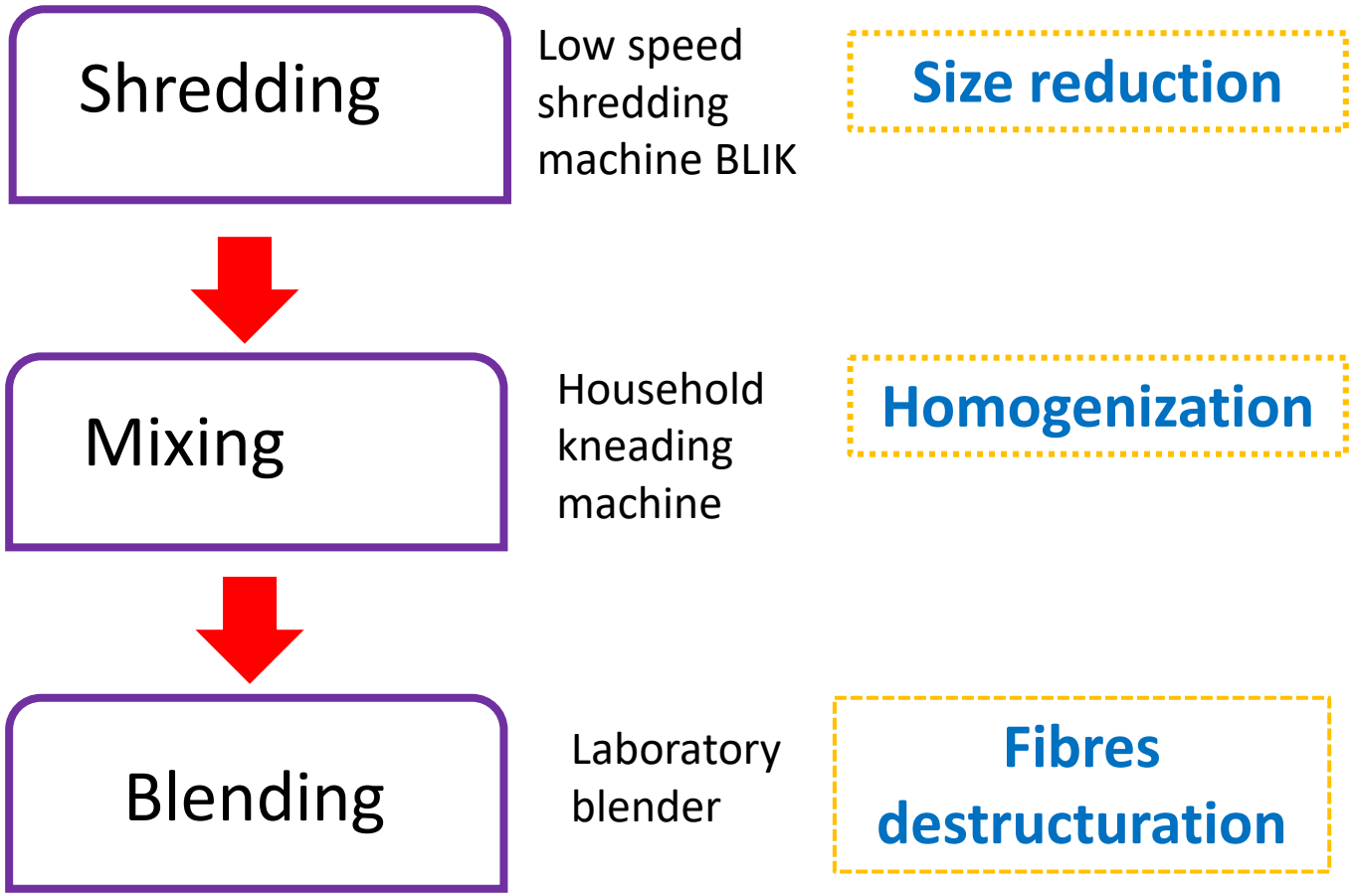
Site #2

✓ Hammer mill (HM2)
✓ Cattle Manure

Site #3

✓ Chain Mill (CM)
✓ Cattle Manure + silage

3- **Lab-scale experiments** to define **functions** & to compare with full-scale mechanical pretreatments



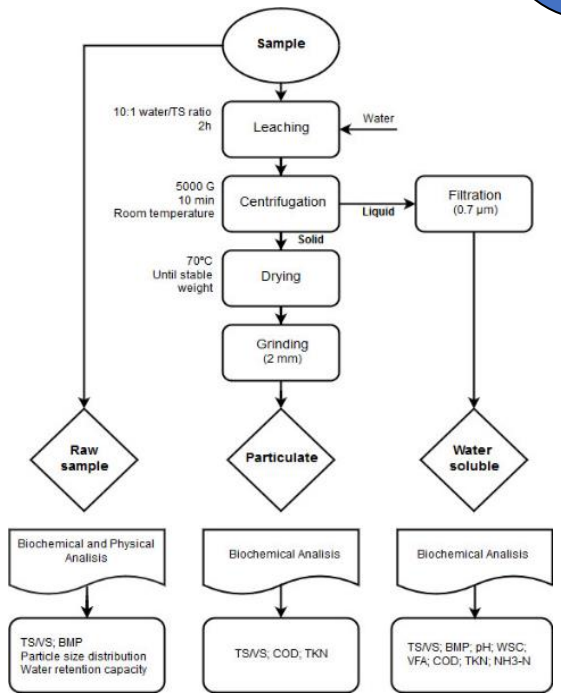
3- **Lab-scale experiments : main effects**

Biomass characterization : The procedure was based on leaching procedure (water extraction) of the raw sample, which enabled the measurement of the contributions of **water-soluble** and **particulate phases** of biomass dedicated to anaerobic digestion

Physical properties	❑ Particle size distribution ❑ Water Retention Capacity ❑ Rheological properties
Biochemical properties	❑ BioMethane Potential (BMP) ❑ OM solubilisation : Chemical Oxygen Demand (COD), (BMP of liquid fraction), nitrogen contents, VFA…

Mechanical pretreatments evaluation effects

Leaching procedure: 10:1 water/TS ratio during 2 h under constant flip-flop rotation (10 rpm)



Teixeira Franco, R., Coarita, H., Bayard, R., & Buffière, P. (2019). An improved procedure to assess the organic biodegradability and the biomethane potential of organic wastes for anaerobic digestion. *Waste Management & Research*, *37*(7), 746–754.

Lab-scale experiments : main effects

Shredding

Indicators	Effects
Particle size distribution	+++ (↘ coarse particles)
Water retention capacity	+
Rheological properties (Apparent viscosity, yield stress)	+++ Until 50% of yield stress reduction Reduction of the apparent viscosity
Solubilisation	++
BioMethane Potential (BMP)	+/- [+ 0-3%]
Kinetic constant (k)	+ [+ 0-85%]

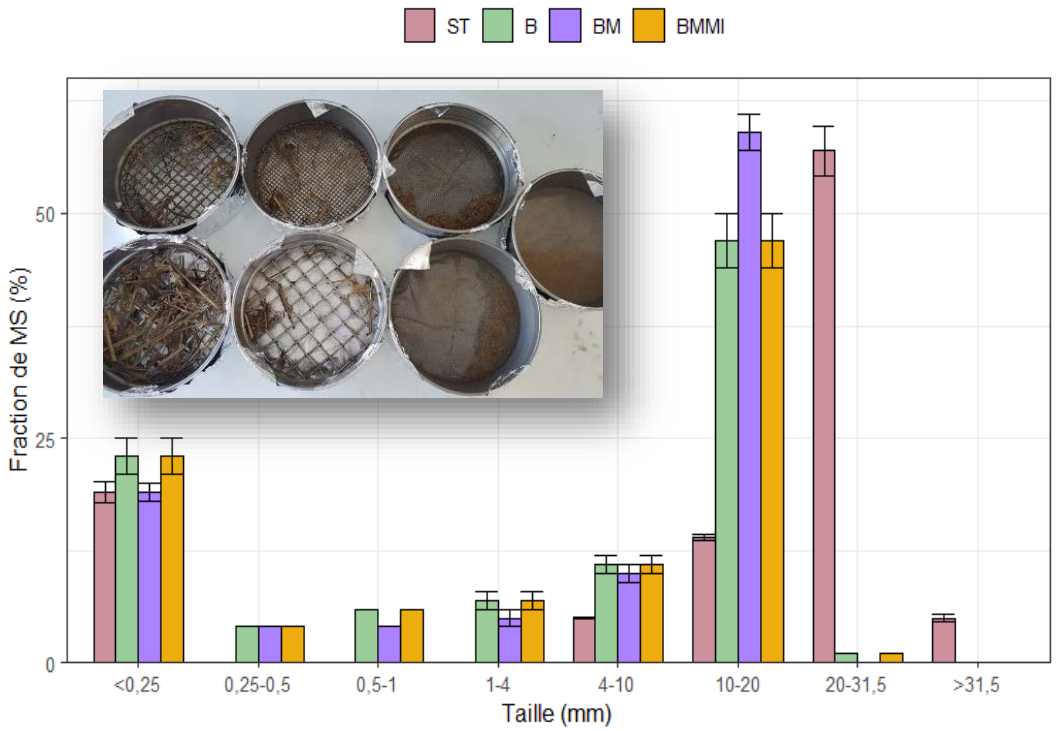


Figure 1. *Particle size distribution, substrate:* ***Silage***
ST: No treatment, B: Shredding, BM: Shredding+ Mixing, BMMI: Shredding + Mixing+ Blending

Lab-scale experiments : main effects

Shredding

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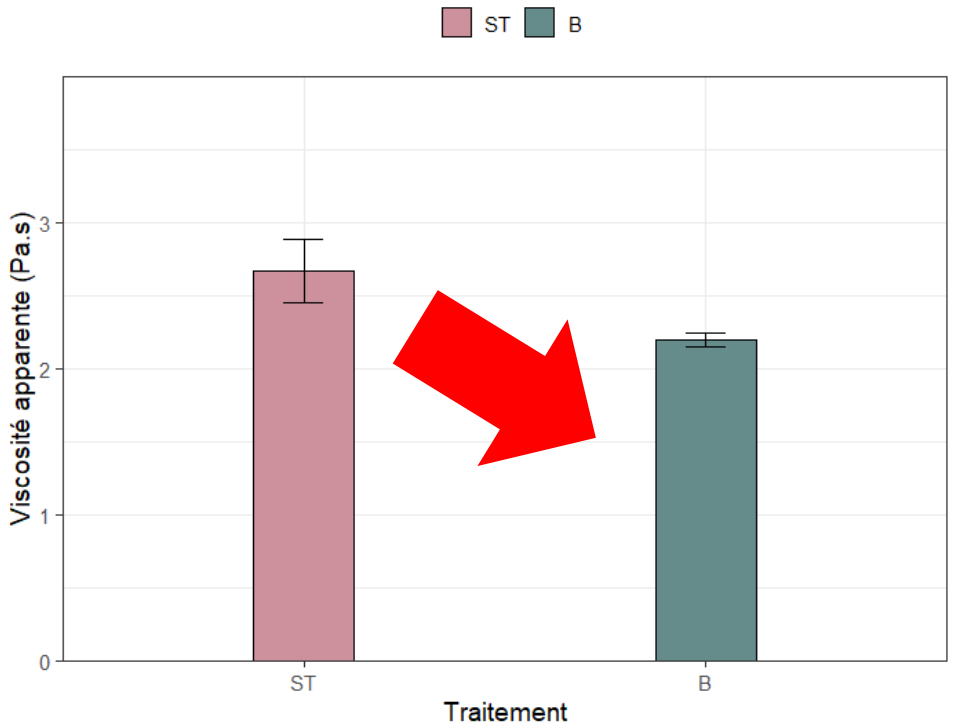
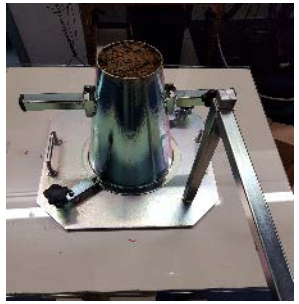


Figure 2. *Apparent viscosity, substrate:* ***cattle manure+ silage****. ST: No treatment to 8%TS, B: Shredding to 10%TS*

Abrams cone



V-funnel

Lab-scale experiments : main effects

Shredding + Mixing

Indicators	Effects
Particle size distribution	-/+
Water retention capacity	+++
Rheological properties (Apparent viscosity, yield stress)	++ Until 30% of yield stress reduction Reduction of the apparent viscosity
Solubilisation	+
BioMethane Potential (BMP)	+/- [+ 0-7%]
Kinetic constant (k)	+ [+ 0-90%]

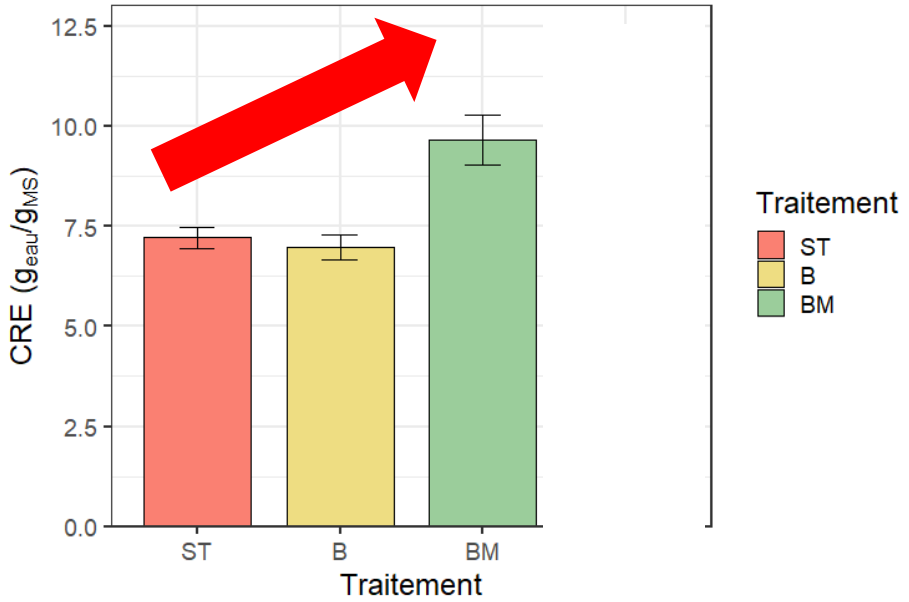


Figure 3. *Water retention capacity, substrate: Silage ST: No treatment, B: Shredding, BM: Shredding+ Mixing, BMMI: Shredding + Mixing+ Blending*

Lab-scale experiments : main effects

Shredding + Mixing + Blending

Indicators	Effects
Particle size distribution	+ (small size particles reduction)
Water retention capacity	+
Rheological properties (Apparent viscosity, yield stress)	++
Solubilisation	+++
BioMethane Potential (BMP)	++ [+ 0-21%]
Kinetic constant (k)	++ [+ 17-90%]

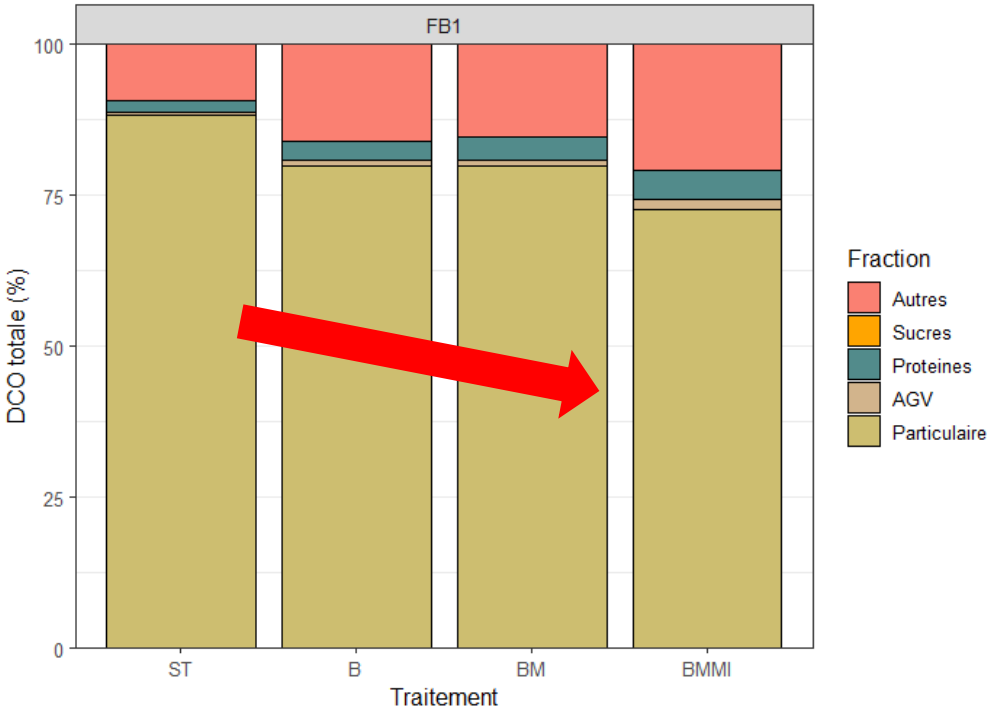


Figure 4. COD distribution. ***Substrate: Cattle manure***. *ST: No treatment, B: Shredding, BM: Shredding+ Mixing, BMMI: Shredding + Mixing+ Blending*

Lab-scale experiments : main effects

Shredding + Mixing + Blending

Indicators	Effects
Particle size distribution	+ (small size particles reduction)
Water retention capacity	+
Rheological properties (Apparent viscosity, yield stress)	++
Solubilisation	+++
BioMethane Potential (BMP)	++ [+ 0-21%]
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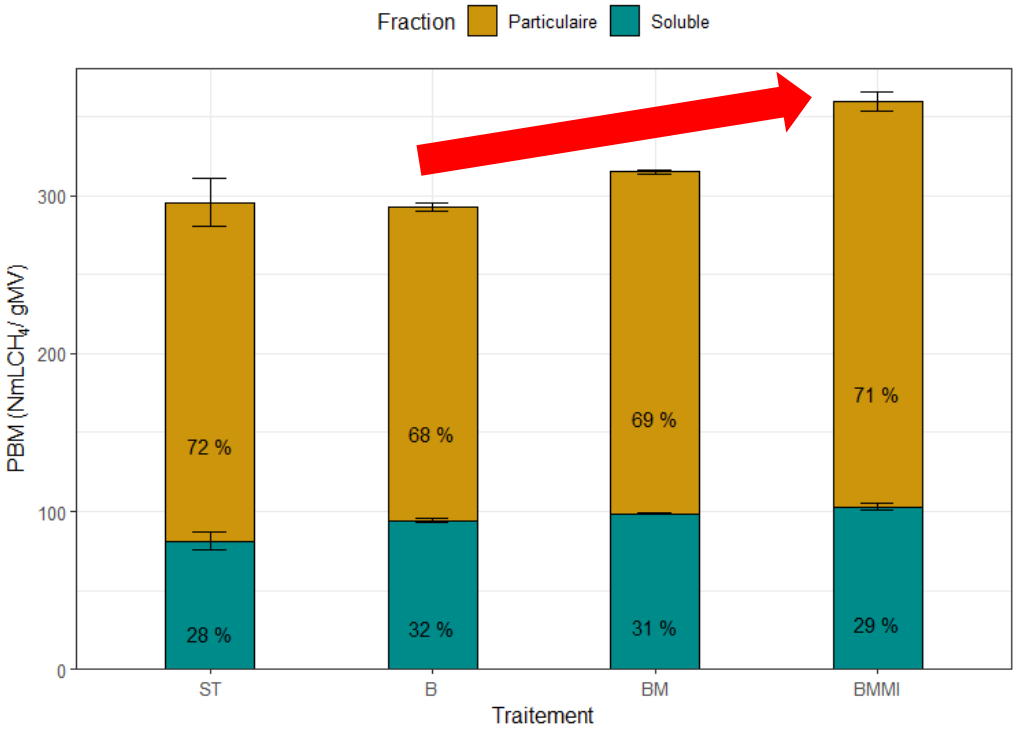
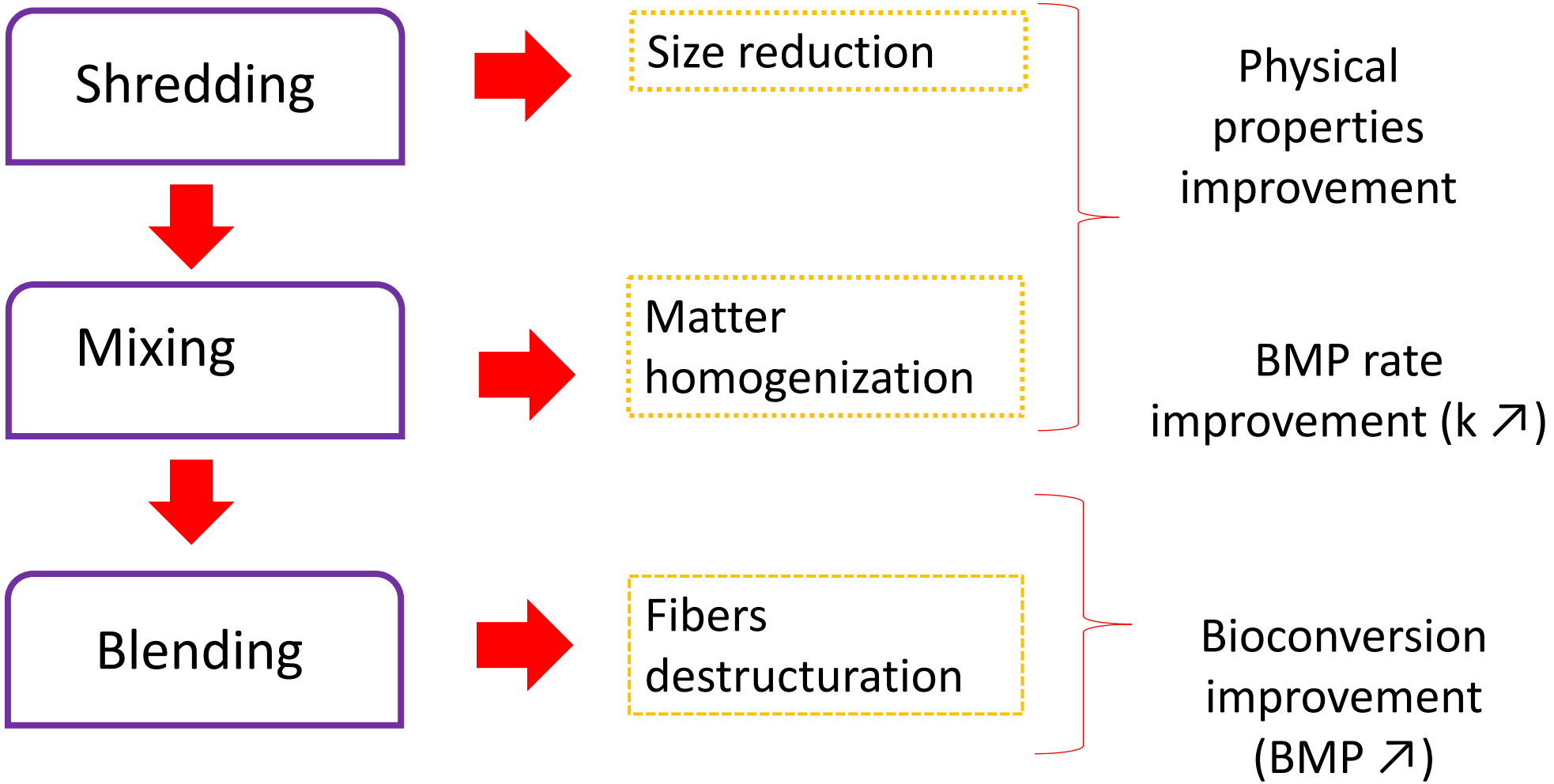


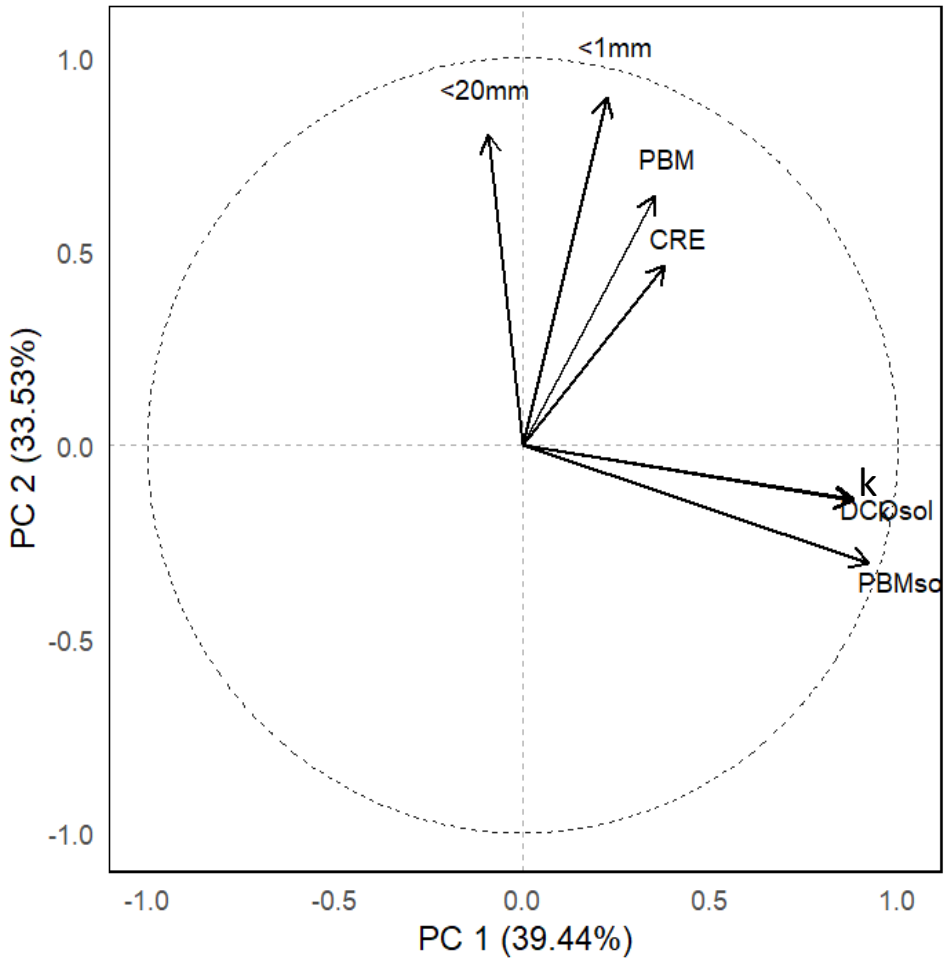
Figure 8. *BMP and soluble BMP contrinution, substrate: **Silage** ST: No treatment, B: Shredding, BM: Shredding+ Mixing, BMMI: Shredding + Mixing+ Blending*

Lab-scale experiments to define **functions and effects**

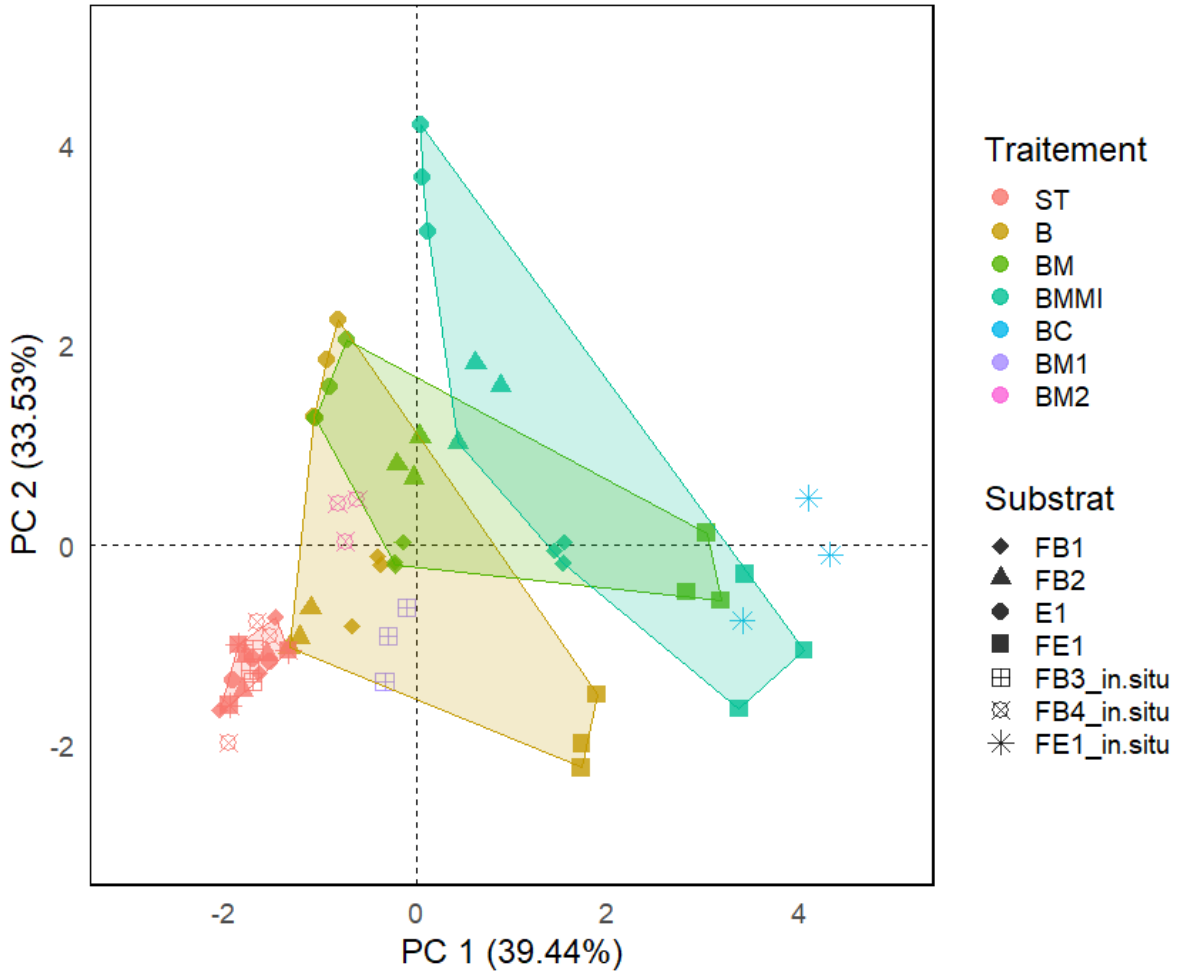


Full-scale pretreatment / lab-scale – statistical analysis (PCA)

Correlation



Function identification



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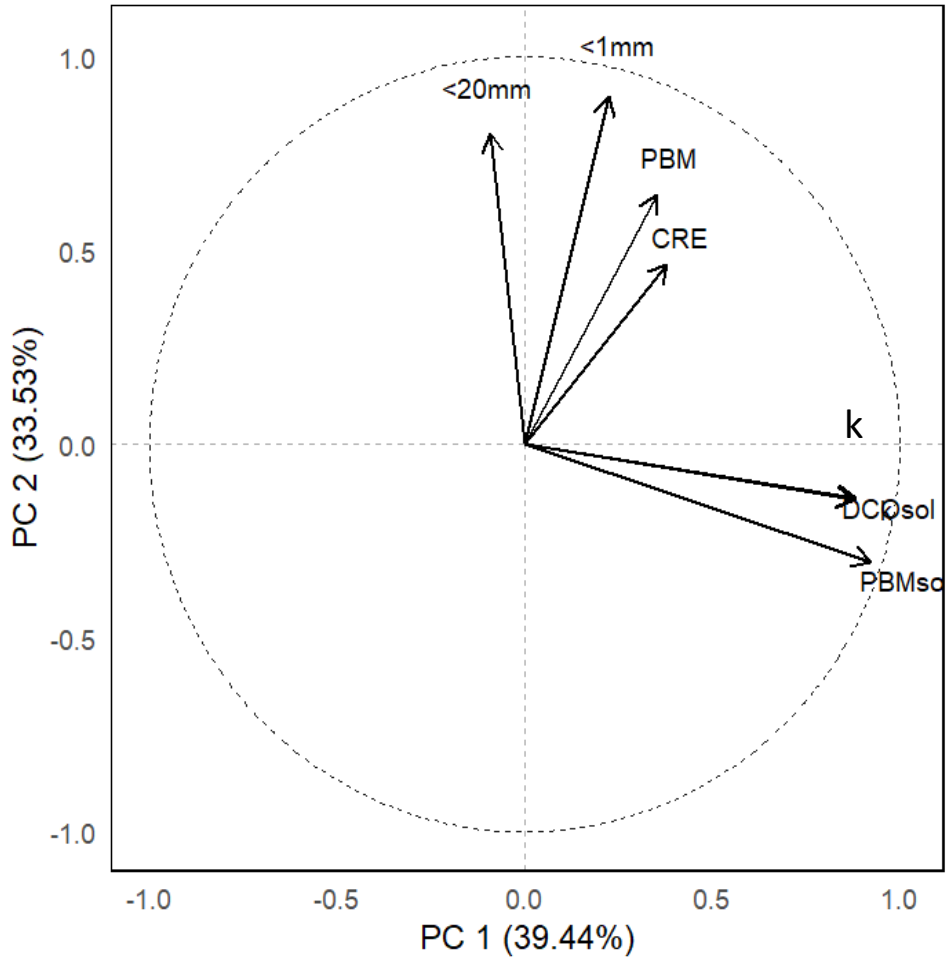
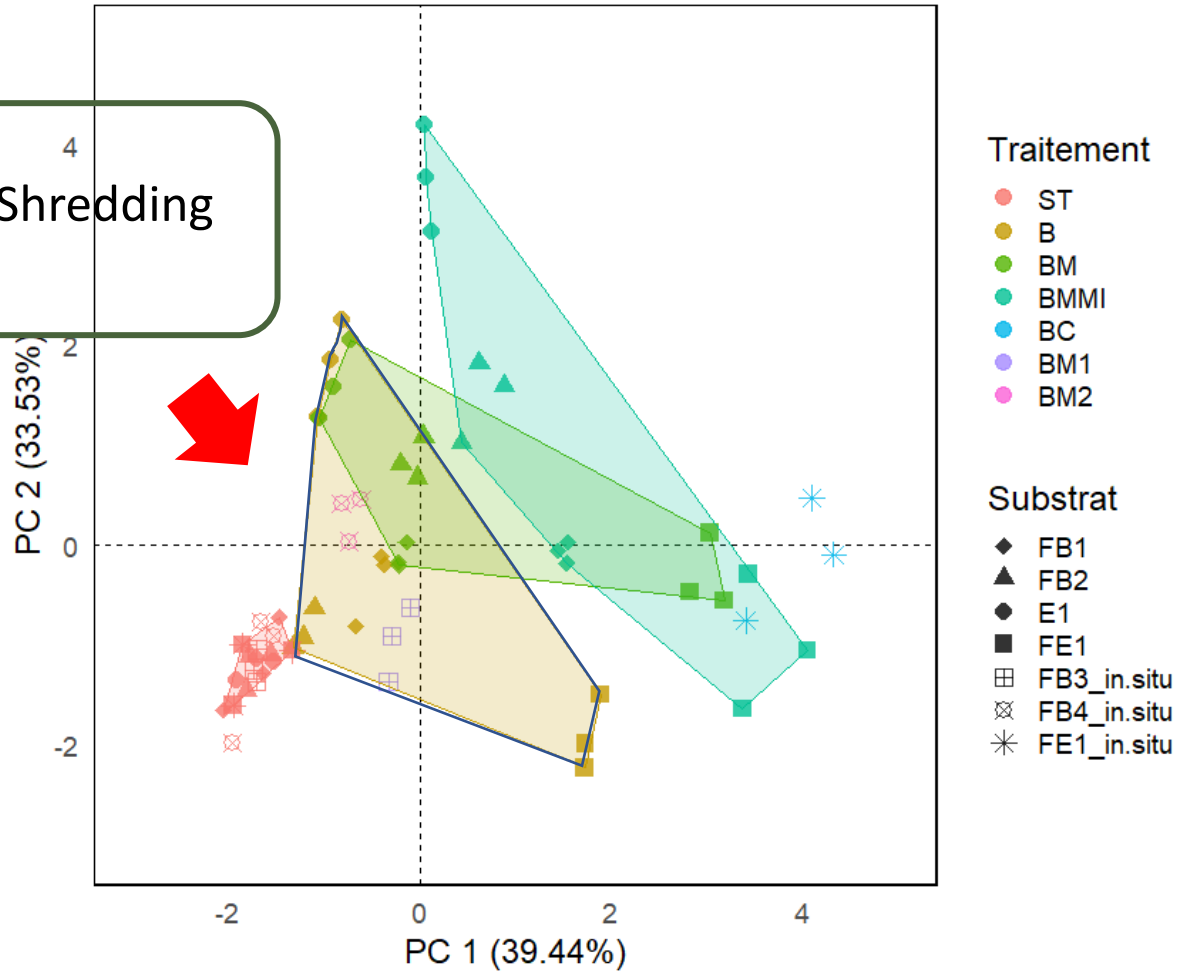


Function identification

Shredding



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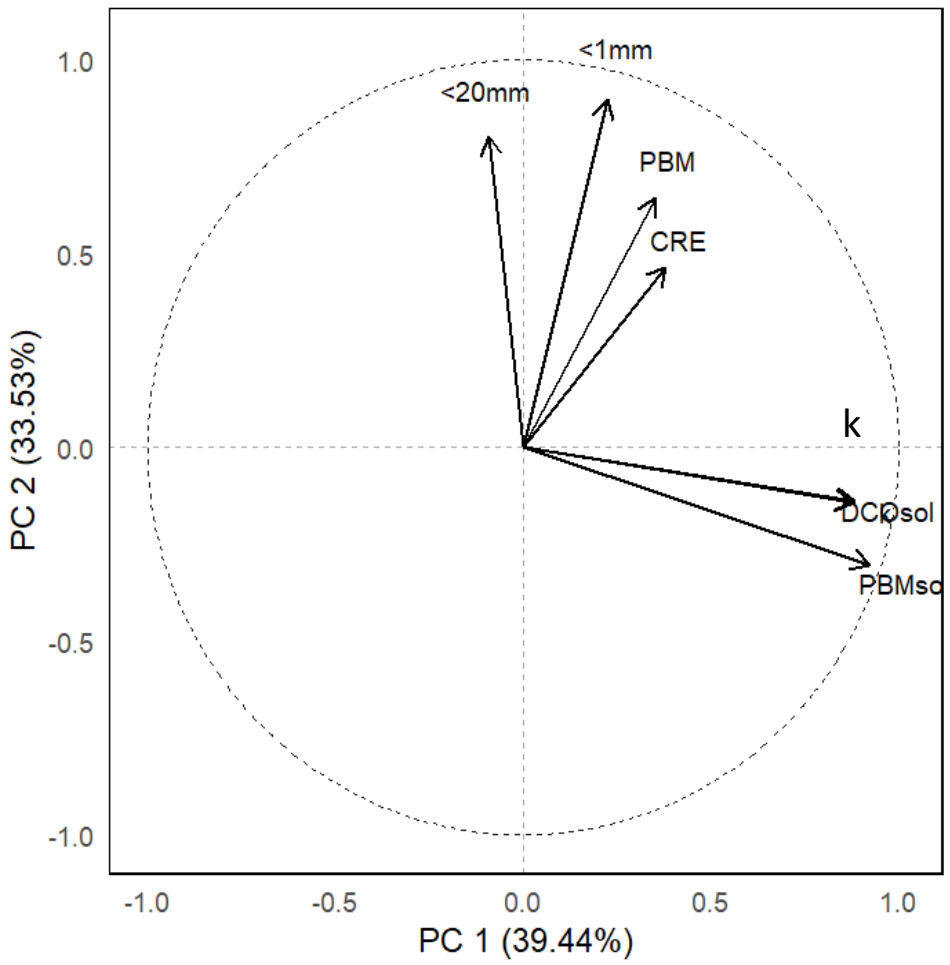

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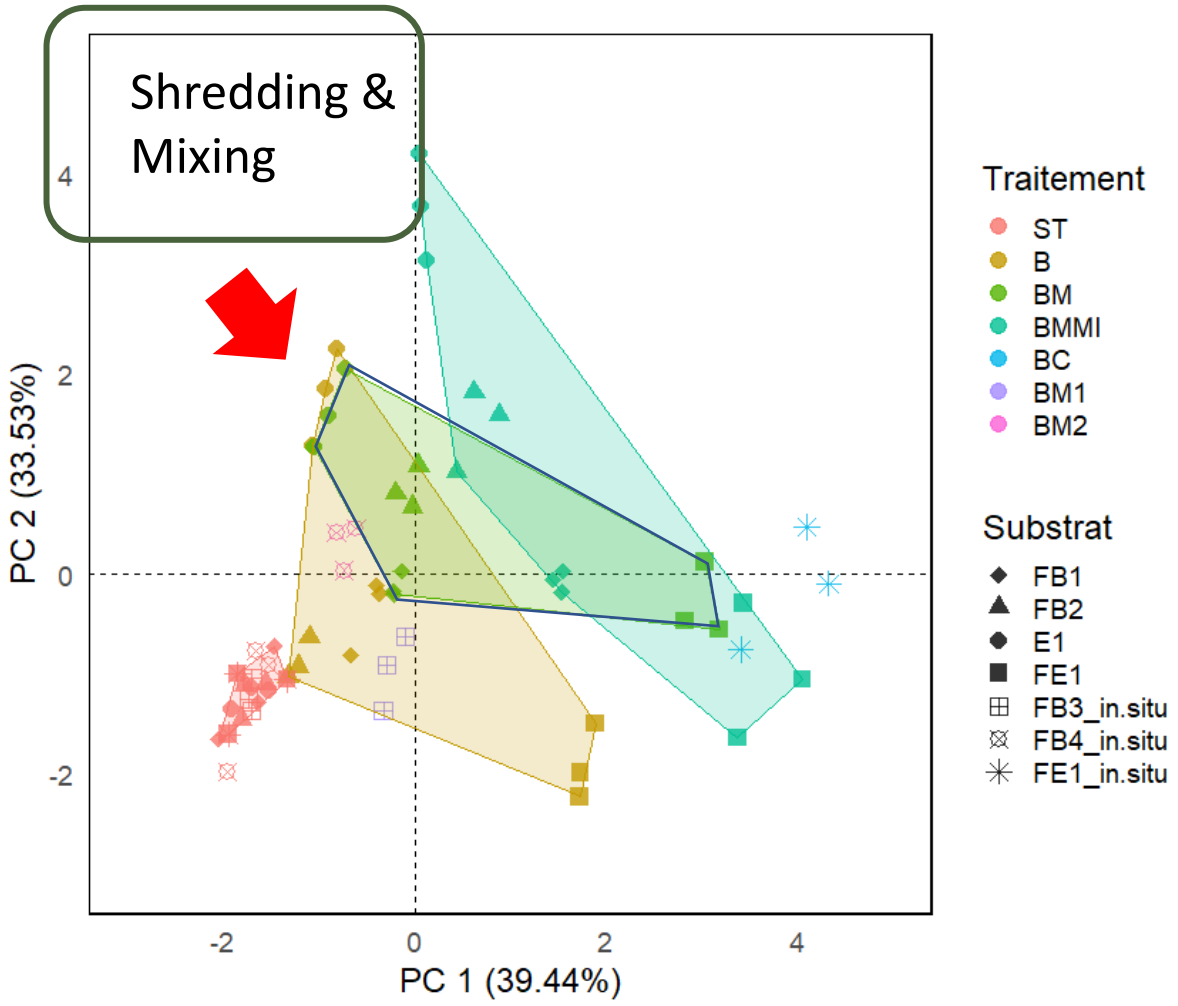

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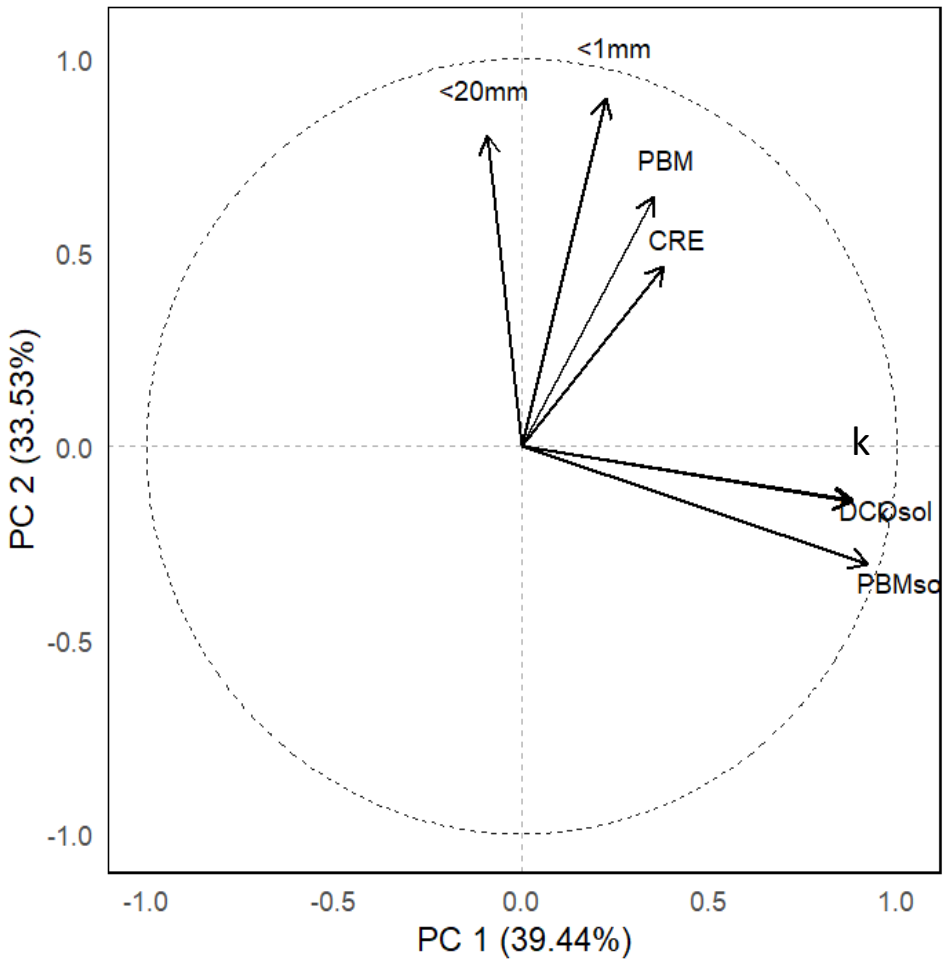

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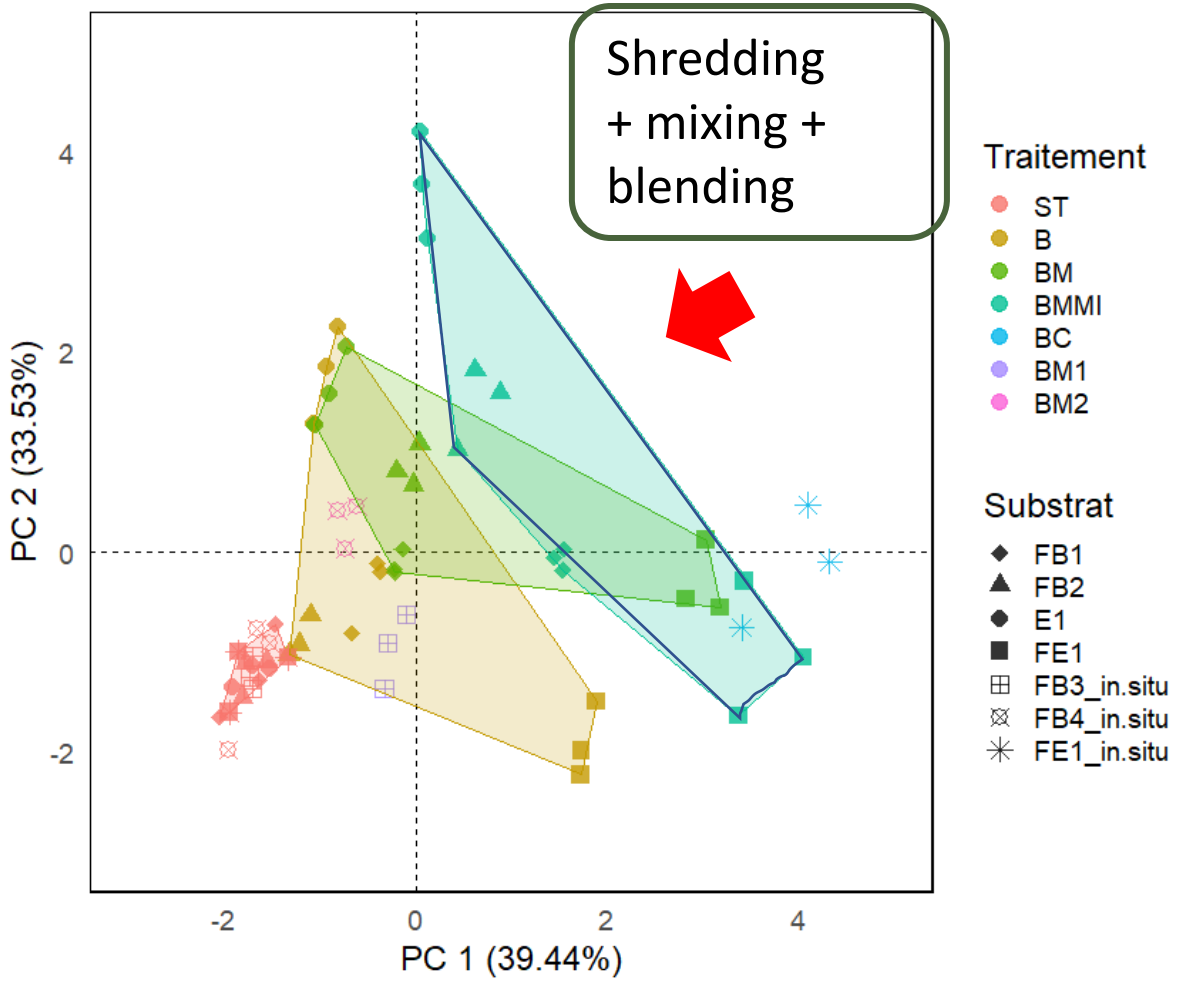
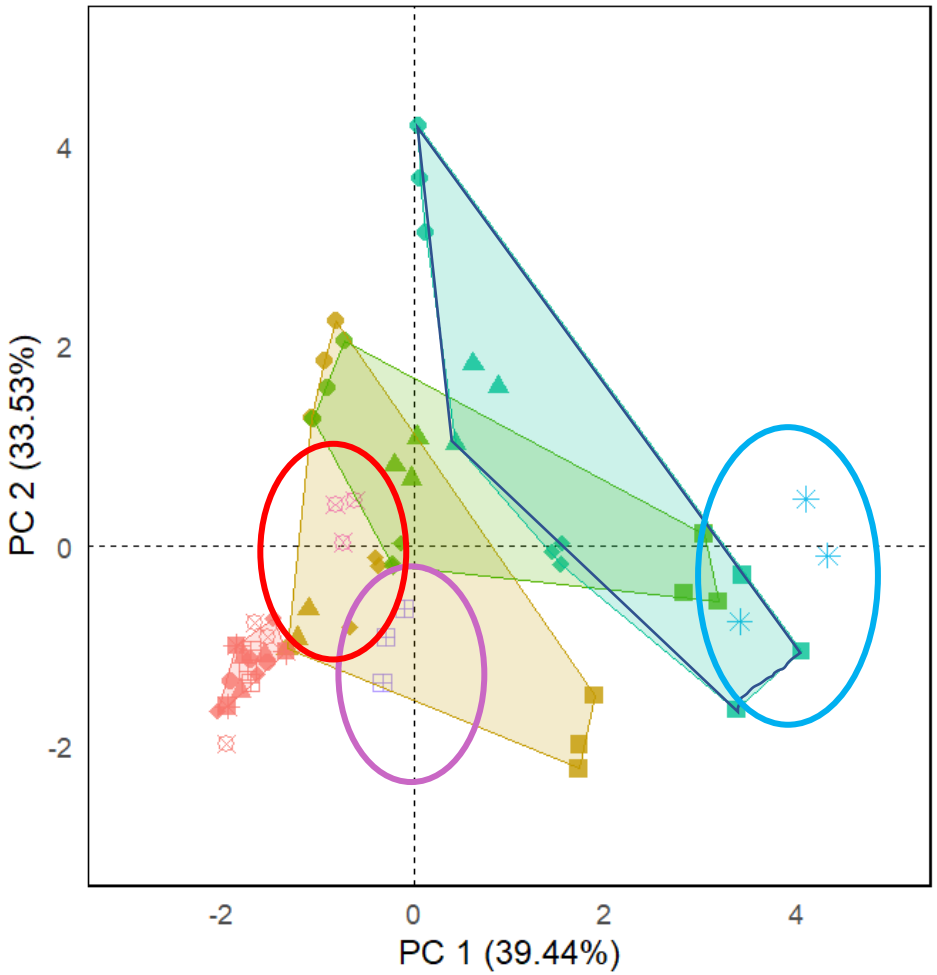


Full-scale pretreatment / lab-scale – statistical analysis (PCA)



Traitement
- ST
- B
- BM
- BMMI
- BC
- BM1
- BM2

Substrat
- FB1
- FB2
- E1
- FE1
- FB3_in.situ
- FB4_in.situ
- FE1_in.situ

Mobile Hammer Mill (HM1) → **Shredding**

Hammer Mill (HM1) → **Shredding + mixing**

Chain Mill (CM) → **Shredding + mixing + blending**

Outlooks

Deeper organic matter characterization	Free and Bound water determination

Improve the comprehension about linked physical mechanisms to methane bioconversion

Further investigations …

Improve the physical methods characterization

ευχαριστώ!

Remy.bayard@insa-lyon.fr

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