Comparison of photocatalytic and hydrolytic pre-treatment of paper-industry lignocellulosic residues to enhance methane yield during anaerobic digestion

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INTRODUCTION: The role of anaerobic digestion

The intensifying global demand for sustainable and renewable energy sources has underscored the importance of anaerobic digestion (AD) as a robust technology for biogas generation from organic waste streams. However, the efficient conversion of lignocellulosic substrates remains a significant technical bottleneck due to their inherent structural recalcitrance. The intricate matrix of cellulose and the "lignin shield" significantly restrict microbial access, thereby hindering enzymatic hydrolysis and overall biodegradability.

Furthermore, specific industrial residues, such as those originating from paper production, often contain significant mineral loads, most notably $CaCO_3$, which can physically encapsulate organic fibers and inhibit methanogenic efficiency.

Primary objectives of pre-treatment:

- ✓ To systematically disrupt the complex biomass architecture, thereby reducing recalcitrance and improving substrate biodegradability.
- ✓ To enhance the accessibility of organic matter for microbial consortia, specifically targeting an increase in cumulative methane yield and hydrolytic efficiency.

MATERIAL PROPERTIES: CPPW and RLCF

This study investigates two distinct waste fractions derived from the paper industry, each presenting unique challenges to anaerobic processing. The physical morphology of these substrates before processing is illustrated in **Figure 1**.

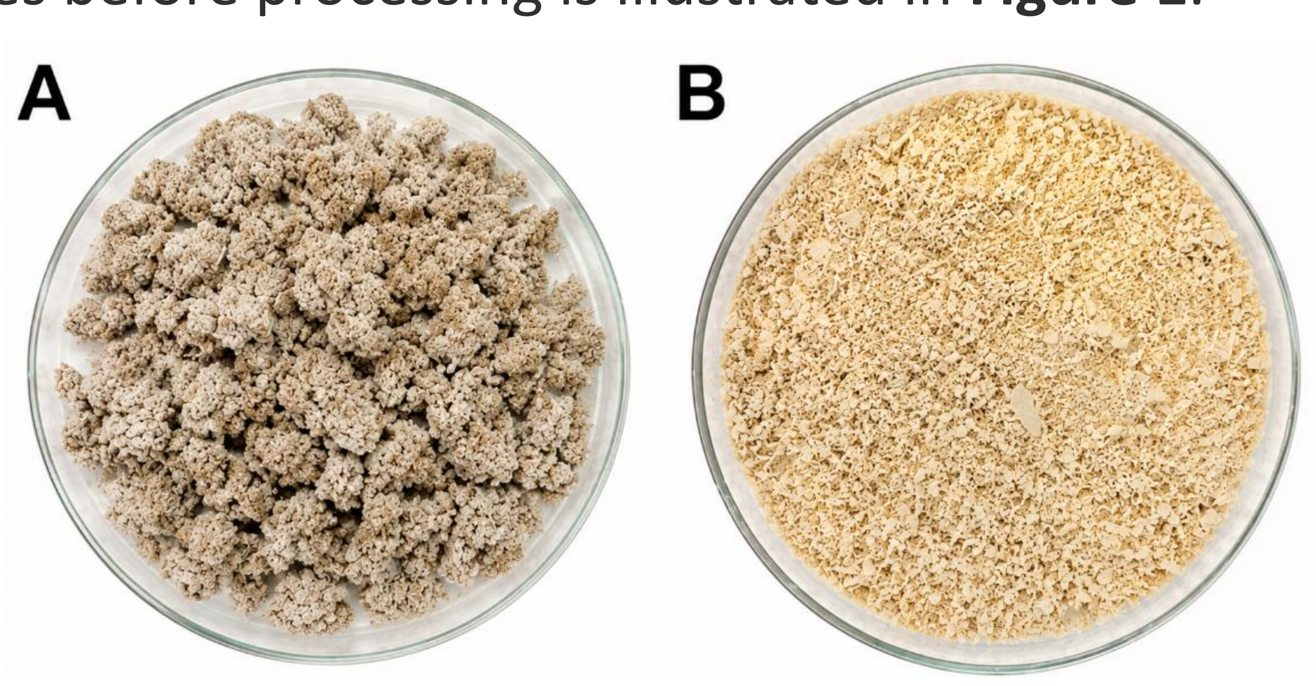


Figure 1 (A) Cigarette paper production waste **(CPPW)**; (B) Residual lignocellulosic paper waste **(RLCF)**.

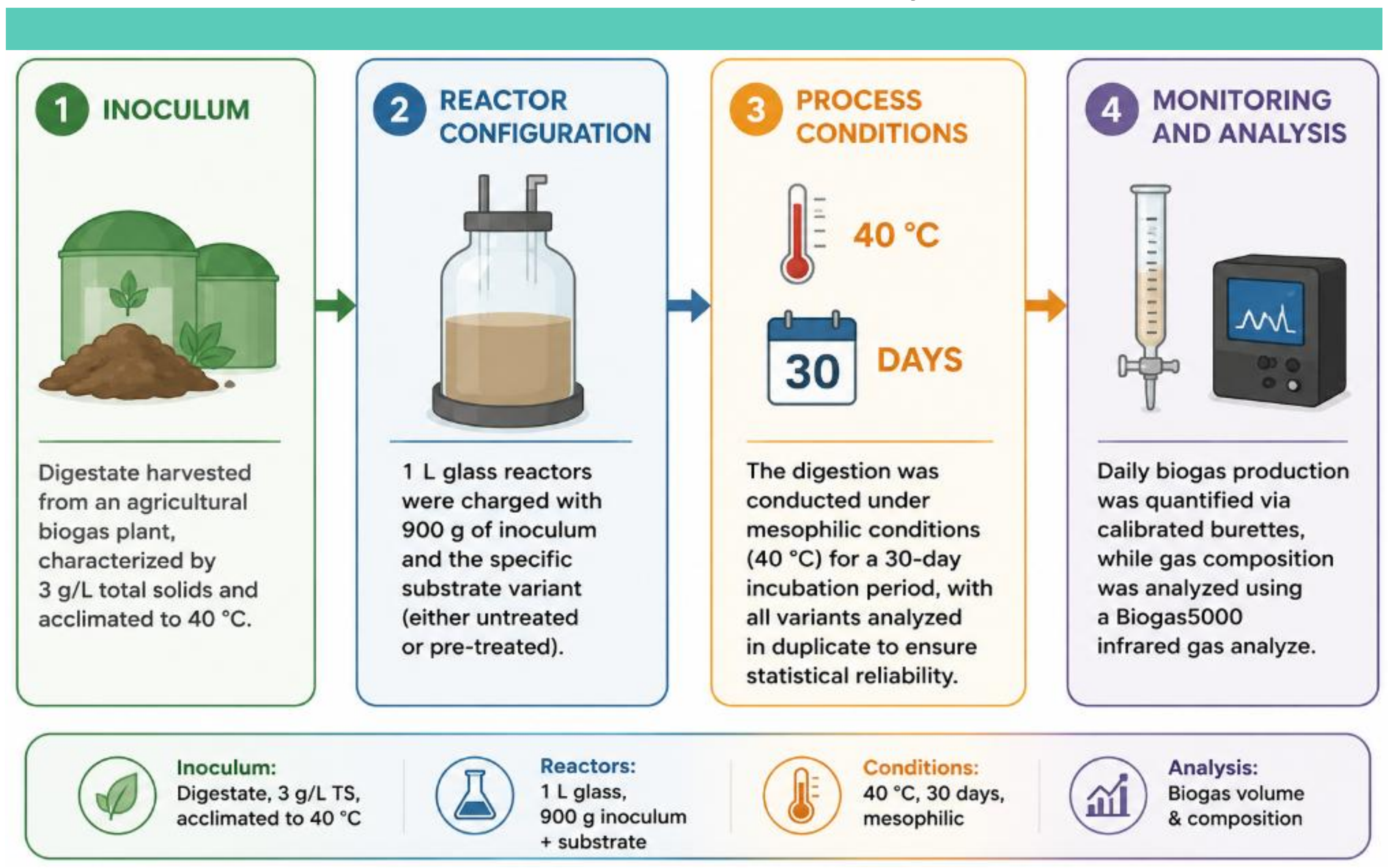
PROPERTY	RLCF	CPPW
Volatile Solids (VS)	99.7 %TS	–
Cellulose Content	46.6 %TS	33.4 %TS
Lignin Content	26.6 %TS	–
Mineral Content ($CaCO_3$)	–	26.0 wt%
Additives	–	1–5% K and Na salts

PRE-TREATMENTS STRATEGIES

Three pre-treatment methods were applied to reduce biomass recalcitrance and improve biodegradability:

- ✓ **Hydrothermal (RLCF):** autoclave treatment at 120 °C or 140 °C.
- ✓ **Photocatalytic/Photolytic (RLCF):** oxidative treatment targeting lignin degradation and improved enzyme accessibility.
- ✓ **Alkaline NaOH (CPPW):** boiling in NaOH solution followed by rinsing to remove $CaCO_3$ and enhance fiber accessibility for methanogenesis.

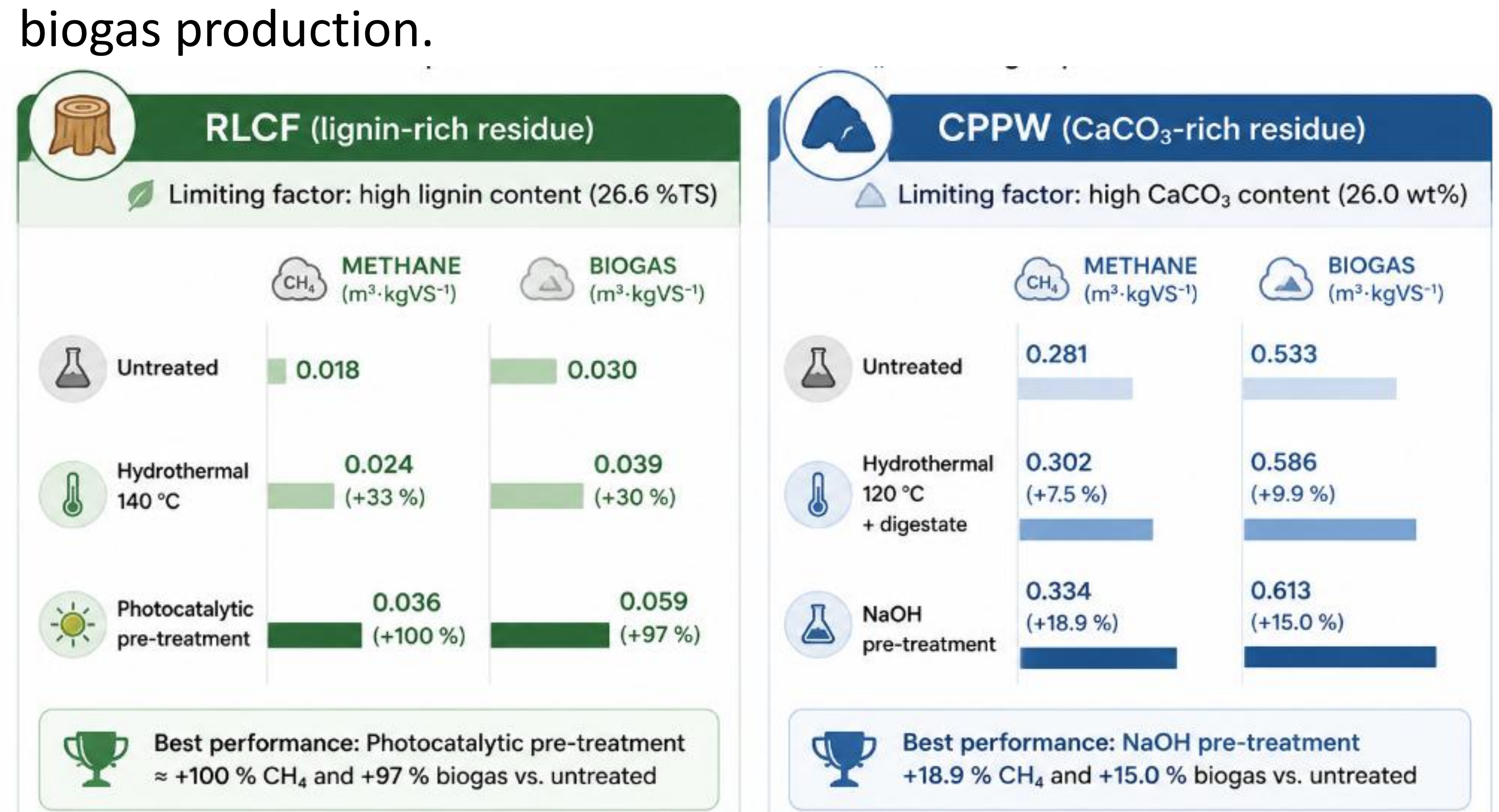
EXPERIMENTAL SETUP: Biochemical CH_4 Potential Test (BMP)



RESULTS

RLCF: The untreated sample reached CH_4 and biogas yields of 0.018 and 0.030 $m^3 \cdot kg_{VS}^{-1}$, respectively. Hydrothermal pre-treatment at 140 °C increased CH_4 production by +33 %, while photocatalytic pre-treatment achieved the highest enhancement, increasing CH_4 and biogas yields by approx. +99 % and +97 %, respectively.

CPPW: The untreated sample produced 0.281 $m^3 \cdot kg_{VS}^{-1}$ CH_4 and 0.533 $m^3 \cdot kg_{VS}^{-1}$ biogas. Hydrothermal pre-treatment at 120 °C with digestate increased CH_4 and biogas yields by +7.5 % and +9.9 %, respectively. The best results were obtained after NaOH pre-treatment, with increases of +18.9 % for CH_4 and +15.0 % for biogas production.



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T A C R

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