Carbon Felt-Induced Direct Interspecies Electron Transfer (DIET) in AnMBR: Effects on Methane Production and Fouling Profile

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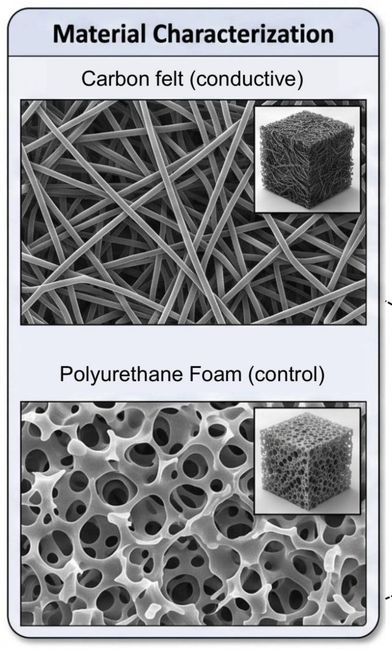
INTRODUCTION & METHODOLOGY

Anaerobic digestion represents a promising route for **energy recovery** though it remains constrained by slow methanogenic kinetics.
Anaerobic membrane bioreactors (AnMBR) enhance performance via biomass retention but membrane **fouling** continues to present an operational challenge.
Stimulating **direct interspecies electron transfer (DIET)** through conductive media offers a potential strategy to intensify biogas production but the long-term impacts of specific material properties remain underexplored.

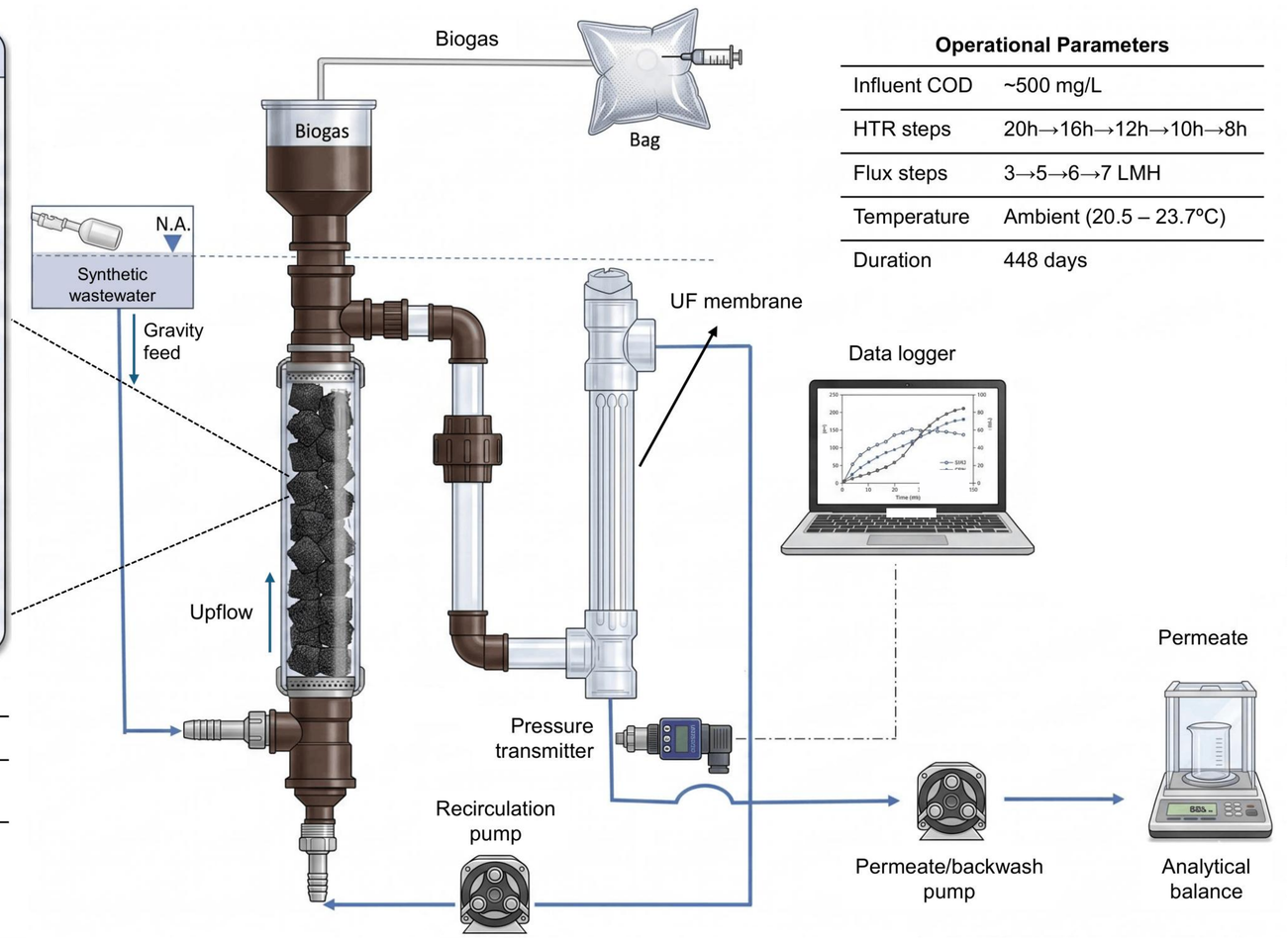
OBJECTIVE & HYPOTHESIS

To evaluate carbon felt as a conductive support material during long-term AnMBR operation to test the hypothesis that a **conductive matrix accelerates methanogenic kinetics via DIET** pathways while modifying biofilm development and membrane fouling interactions.



Support Media (210 units/reactor)

PUF	CF
Non-conductive	Conductive ($4.2\ 10^{-2}$ S.m^{-1})
104.55 cm^2/g	32.03 cm^2/g



Operational Parameters

Influent COD	~500 mg/L
HTR steps	20h→16h→12h→10h→8h
Flux steps	3→5→6→7 LMH
Temperature	Ambient (20.5 – 23.7ºC)
Duration	448 days

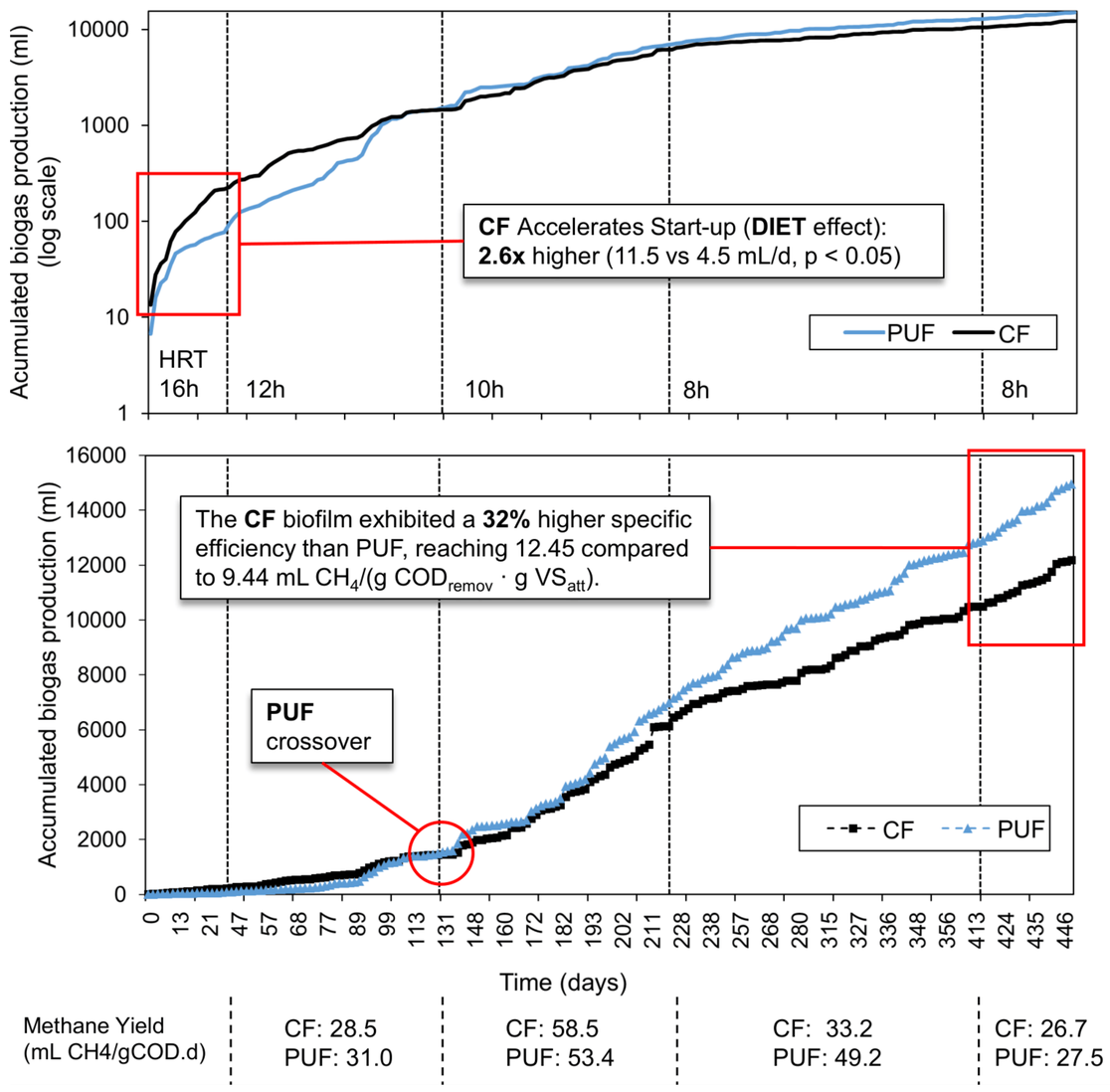
RESULTS AND DISCUSSION

COD Removal

Both configurations sustained stable **total COD removal efficiencies ~90%**, with permeate COD consistently maintained below 90 mg/L. The high organic matter removal was suggested to be primarily governed by the **physical retention barrier of the membrane**.

Biogas Production

Stable methane content exceeding 70% in both configurations ($p > 0.05$). Driven by its superior macroporosity, the PUF matrix retained 47 mgVS$_{att}$/g compared to 26 mgVS$_{att}$/g for the CF support.

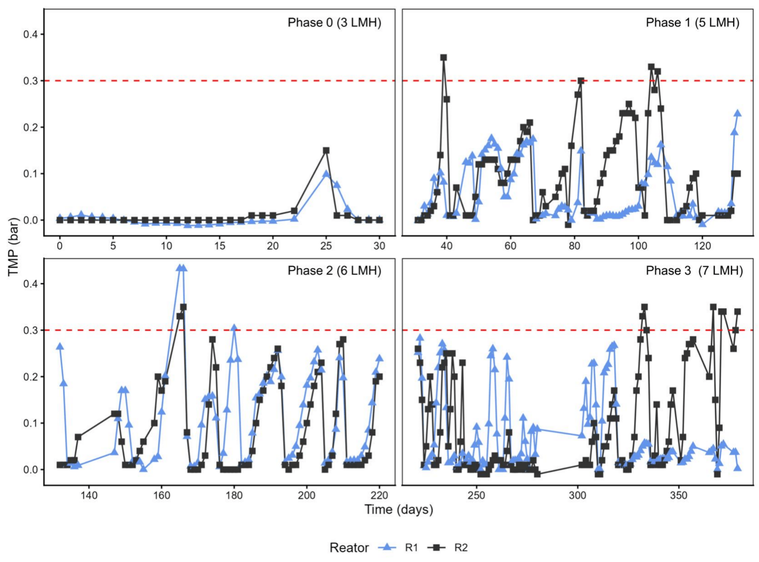


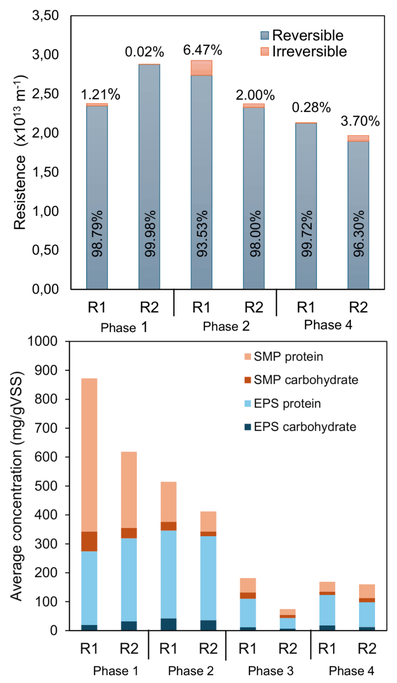
Continuous biomass accumulation favored PUF over CF in Phase 3 (49.2 vs 33.2 mL/g COD). A bed-loosening intervention then removed excess biofilm, dropping overall yields but closing the volumetric gap in Phase 4. Crucially, final biomass normalization revealed that CF achieved a 32% higher specific efficiency, confirming its superior intrinsic kinetic activity.

Membrane Fouling

The CF reactor exhibited higher initial transmembrane pressure (TMP) during Phases 1 and 2, suggesting a potential association with accelerated biological deposition triggered by DIET pathways.

These temporal TMP profiles directly correlate with resistance-in-series data, where the reversible cake layer accounted for 93.5% to 99.9% of total filtration resistance across all phases.





Biopolymer reduction suggested biofilm maturation, TMP elevated due to flux-induced physical cake compression. Sharp drops in total system resistance were primarily modulated by the frequency of external washings.

CONCLUSIONS

- Conductive carbon felt **accelerated initial methane production rates**, suggesting that electrical conductivity stimulated Direct Interspecies Electron Transfer (DIET) pathways during start-up.
- Long-term performance revealed a balance between properties: the polyurethane foam maximized total volumetric biogas through **superior biomass accumulation**, whereas the carbon felt maintained an enhanced **specific metabolic activity** per gram of biomass.
- Fouling appeared predominantly reversible, and the type of support media did not seem to significantly influence long-term filterability. The observed TMP elevation was driven by flux-induced physical **cake compression**, confirming the need for dedicated fouling mitigation strategies beyond crossflow hydrodynamic management during operation.

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