# Close the loop: study of the effect of digestate derived biochar on anaerobic digestion of organic fraction municipal solid waste.

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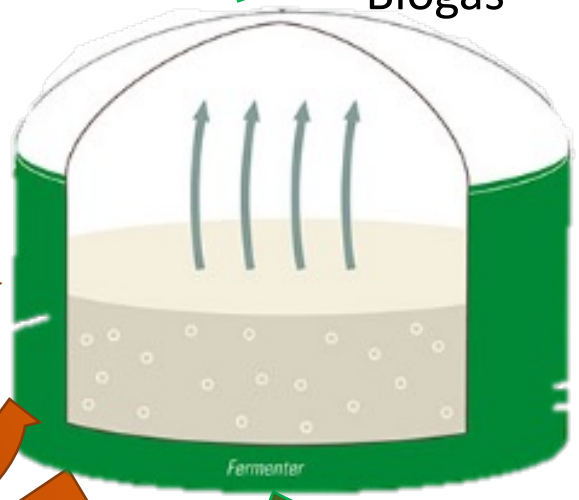
# Introduction to anaerobic digestion

Waste biomasses

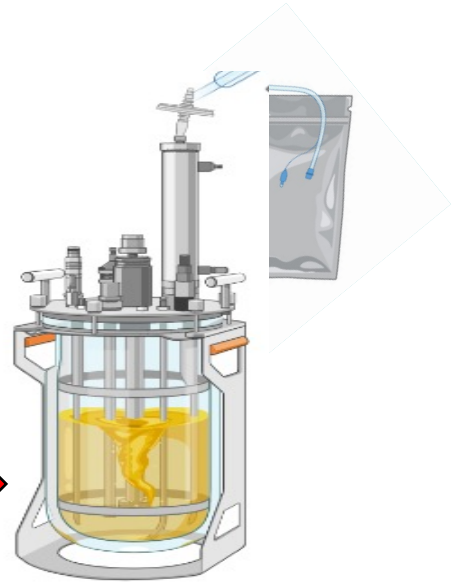
Biogas




Digestate

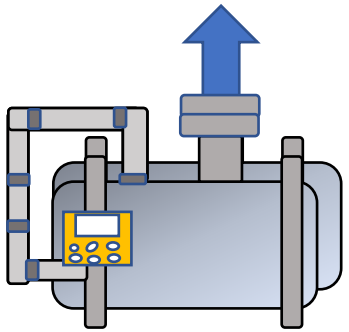
# Our approach

OFMSW



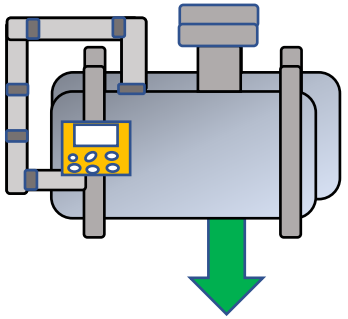
Digestate

Bio-oil and pyrogas



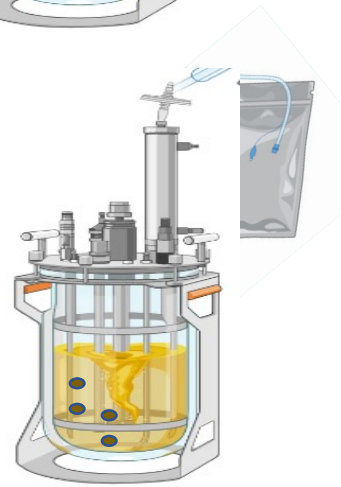
biochar

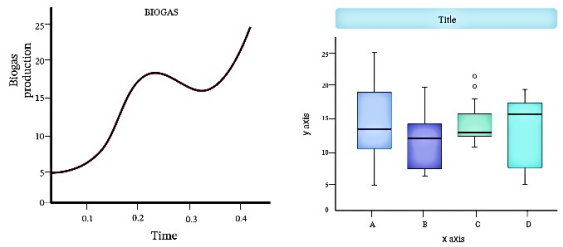
+ KOH

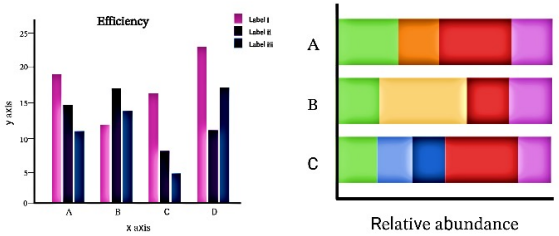


Bio-oil and pyrogas

KOH - biochar

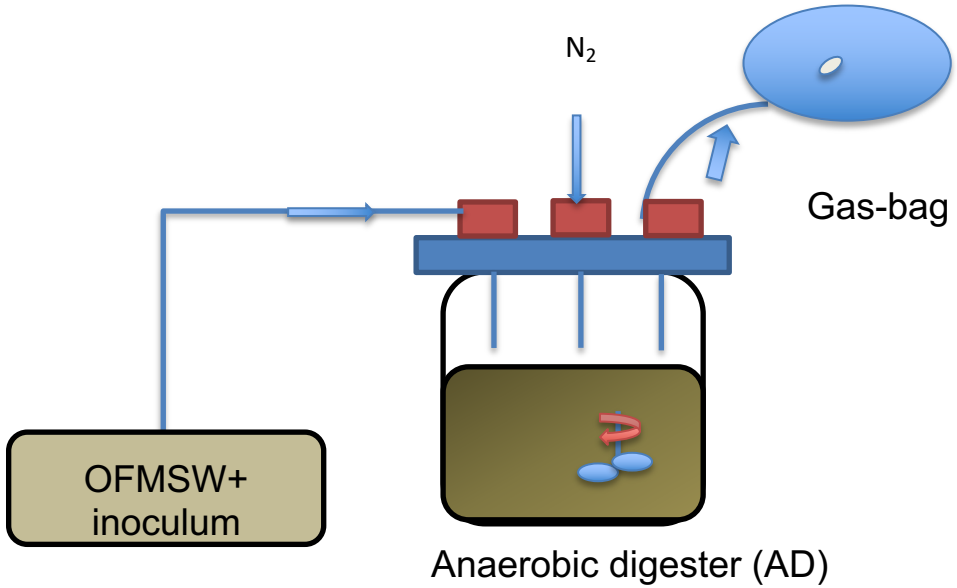


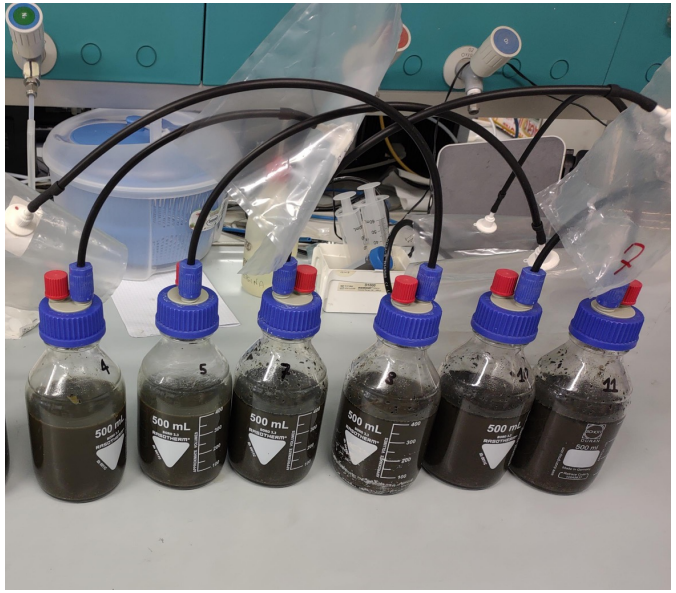


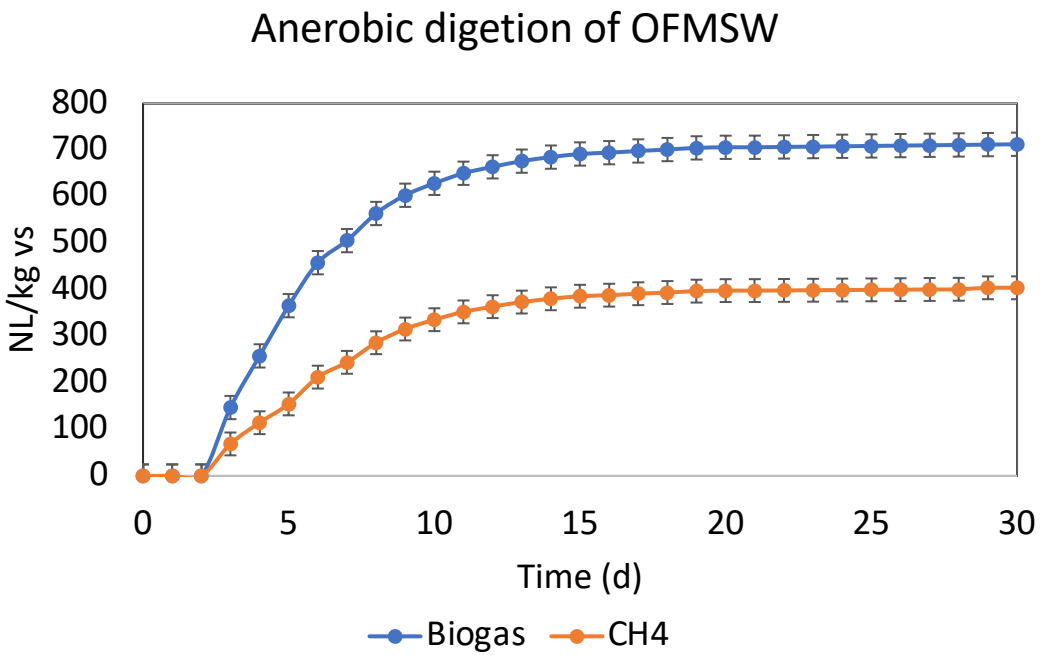
# Anaerobic digestion conditions

- Batch mode feed
- Total solid (TS) (%) feed: 6 %
- Substrate (S): organic fraction municipal solid waste (OFMSW) from San Carlo S.p.A. (Fossano, Italy)
- Inoculum (I): digestate of cow-agricoltural waste (Candiolo, Italy)
- S:I = 2:1
- T = 37 °C
- Volume = 500 mL
- Test in triplicate



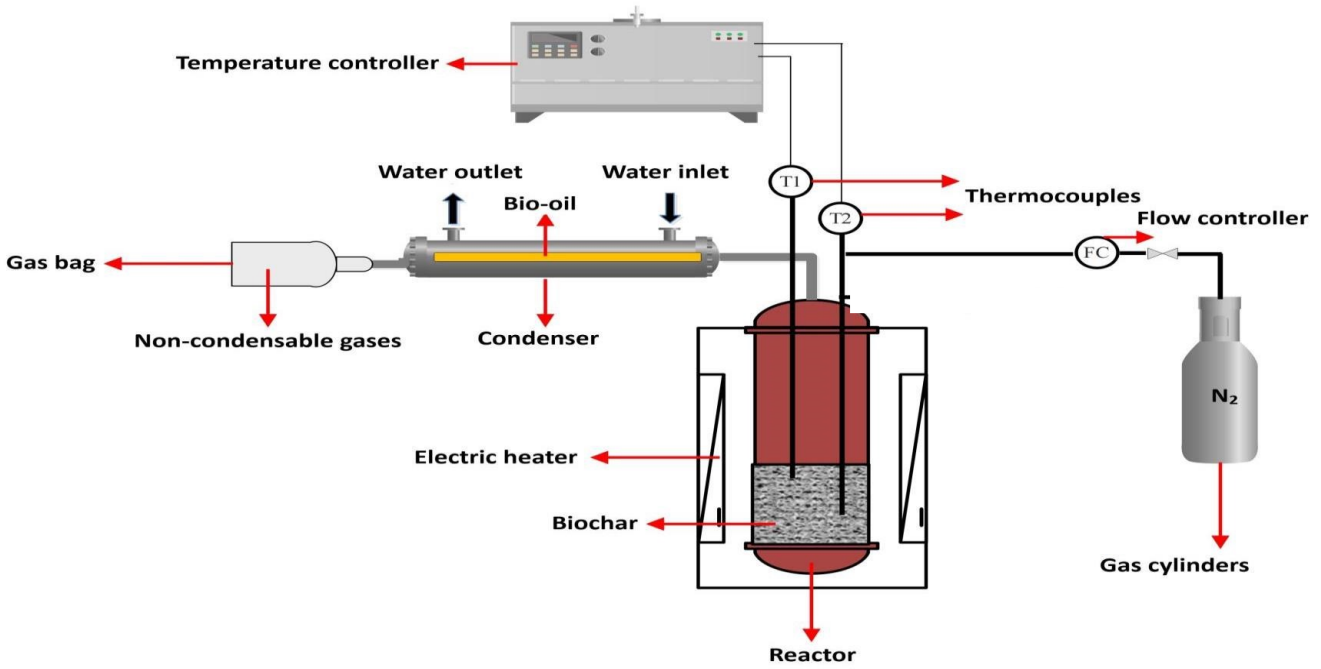
# Anaerobic digestion performance

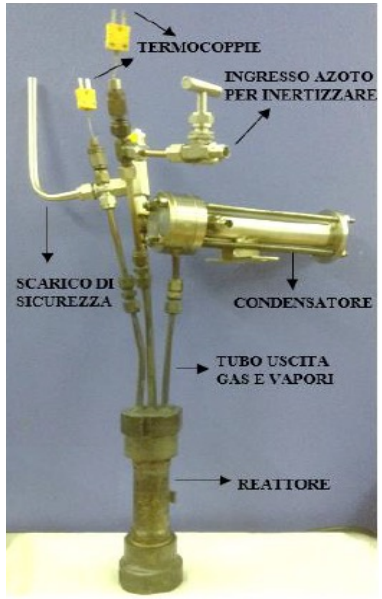



| | OFMSW | | Inoculum CAS | | Digestate | |
|---|---|---|---|---|---|---|
| | mean | dev.st | mean | dev.st | mean | dev.st |
| TS (%) | 19 | 2.3 | 6 | 0.1 | 5.7 | 0.99 |
| VS/TS (%) | 97 | 1.8 | 67.9 | 1 | 52 | 2.76 |
| C (%) | 45.7 | 2.7 | 40.6 | 0.6 | 35.34 | 1.34 |
| H (%) | 6.1 | 0.3 | 3 | 0 | 6.08 | 2.1 |
| N (%) | 2.4 | 0.2 | 7.9 | 0.1 | 3.4 | 0.45 |
| S (%) | 0.2 | 0.1 | 0 | 0 | 1.45 | 0.01 |
| O /%) | 45.4 | 3.1 | 48,5 | 2.1 | 49.73 | 0.23 |
| pH | 5.3 | 0.2 | 7.7 | 0.1 | 6.9 | 0.15 |

# Slow pyrolysis conditions

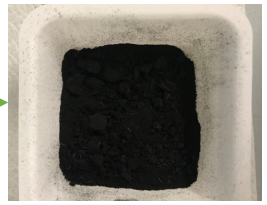
- Fixed bed reactor
- Feedstock:
  - KOH pre-treated digestate at KOH/digestate ratios = 1:4 ; 1:2 ; 1:1
  - Digestate as well
- T = 400, 500, 600 °C
- Heating rate = 10 °C/min
- Residence time = 1h
- Volume = 100 mL




Biochar from KOH-pre-treated digestate

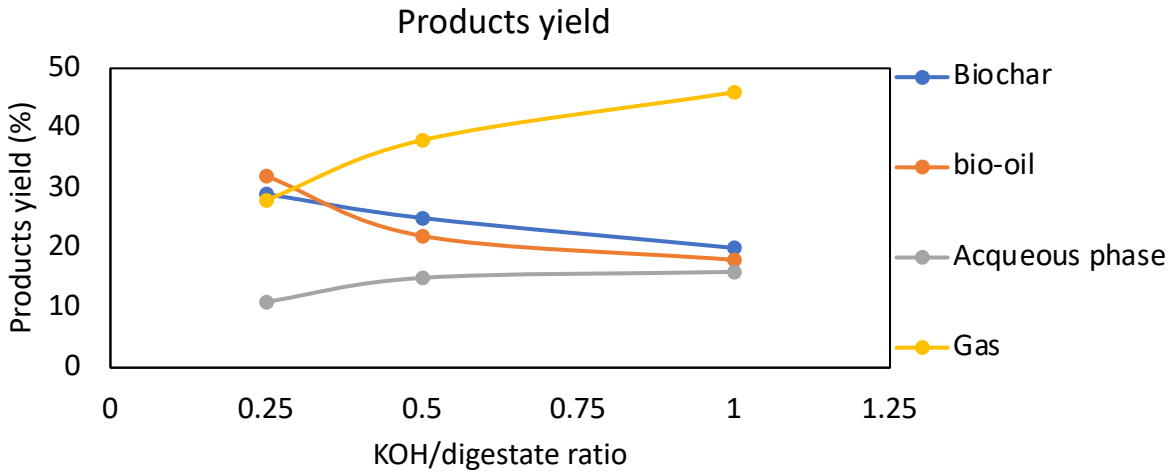

Biochar from digestate

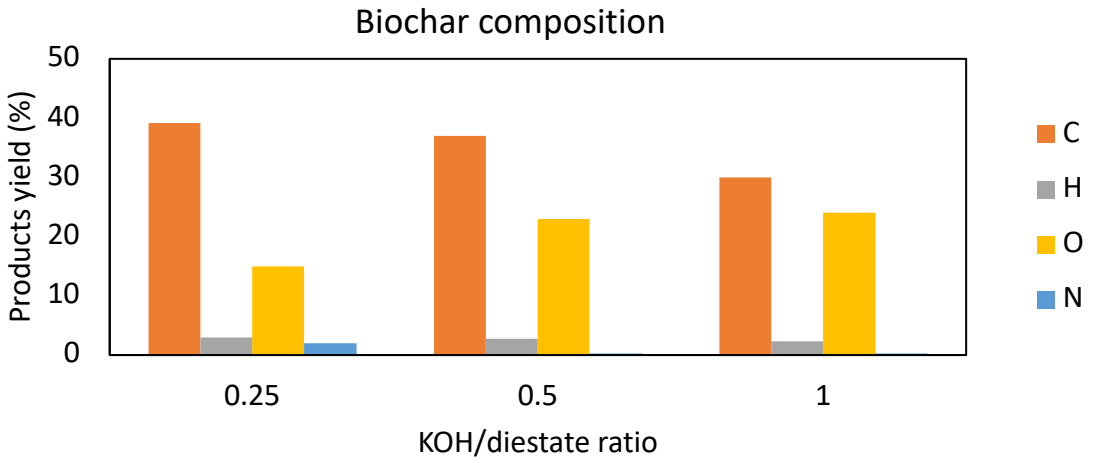


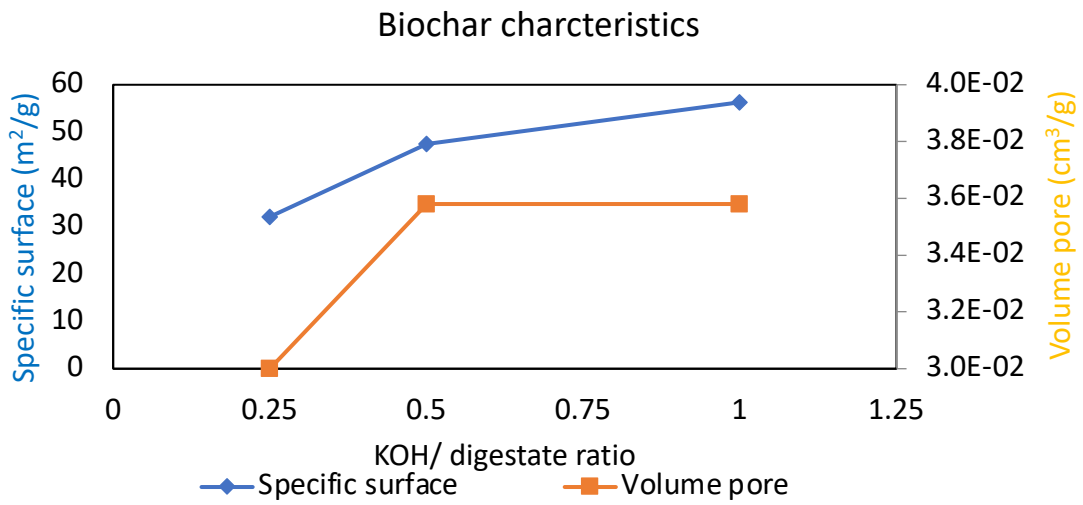
Chen et al. 2023. https://doi.org/10.1016/j.apenergy.2020.115730

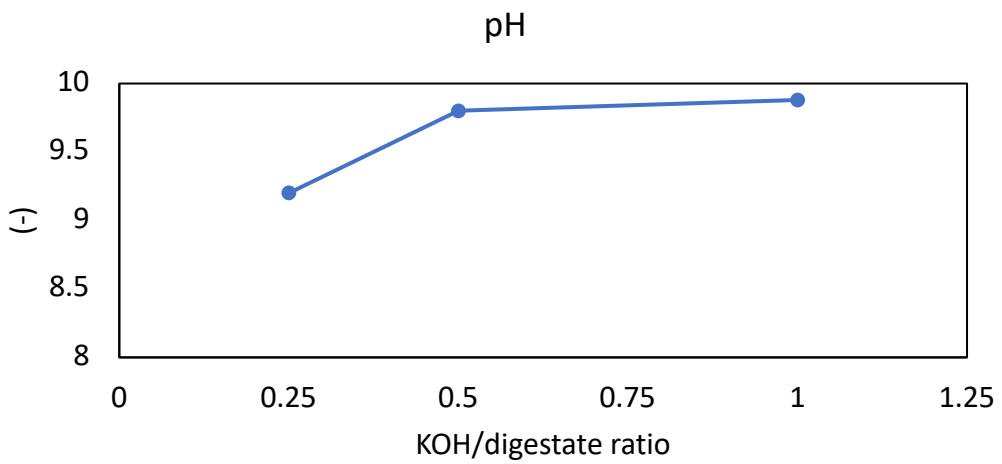
# Slow pyrolysis : study of KOH effect

T = 600°C

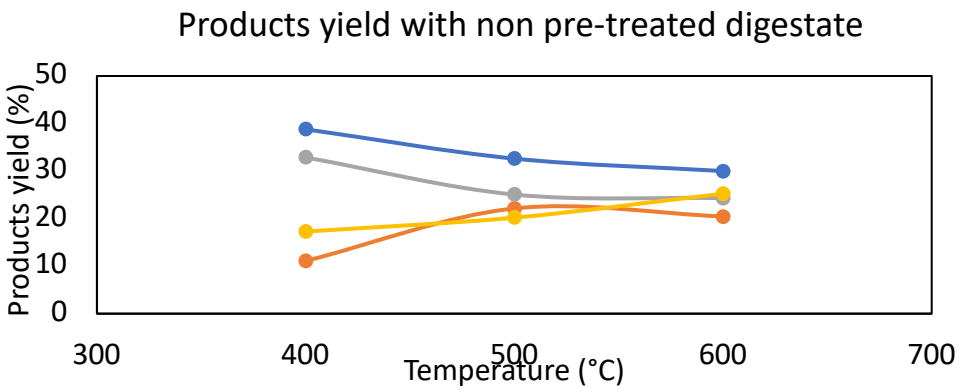


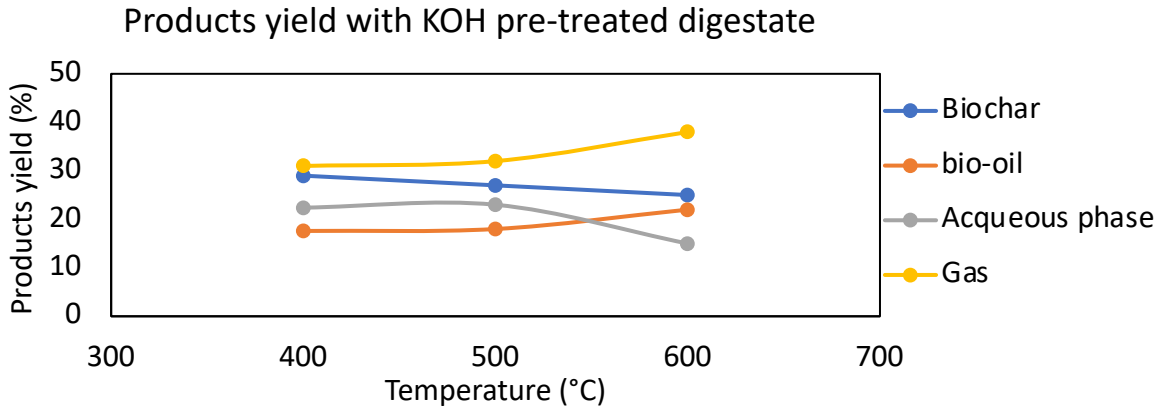



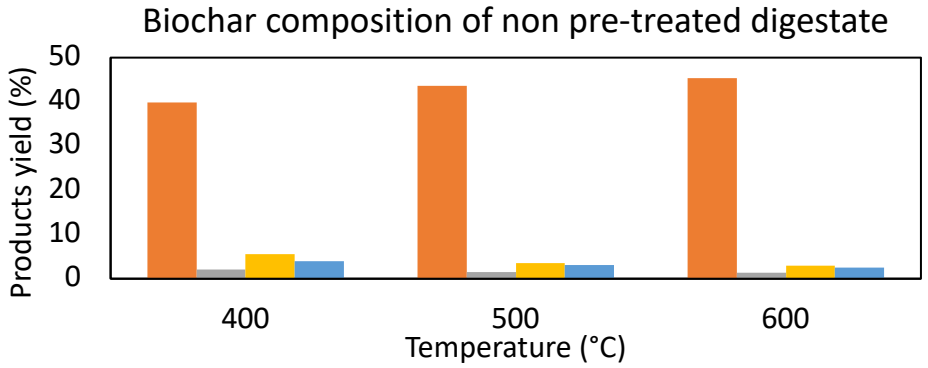



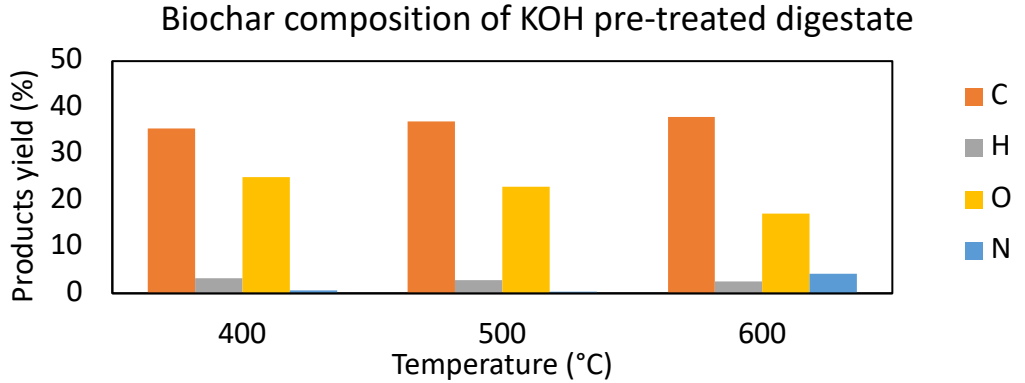



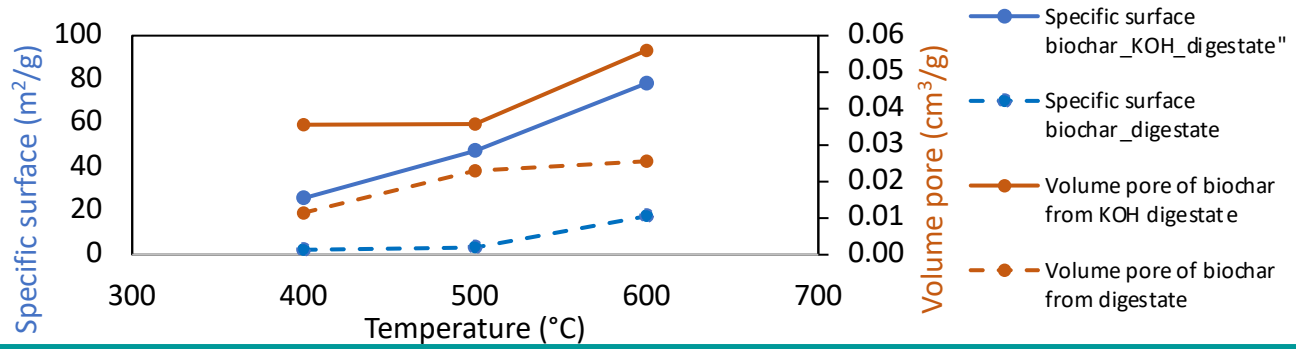
# Slow pyrolysis: study of temperature effect

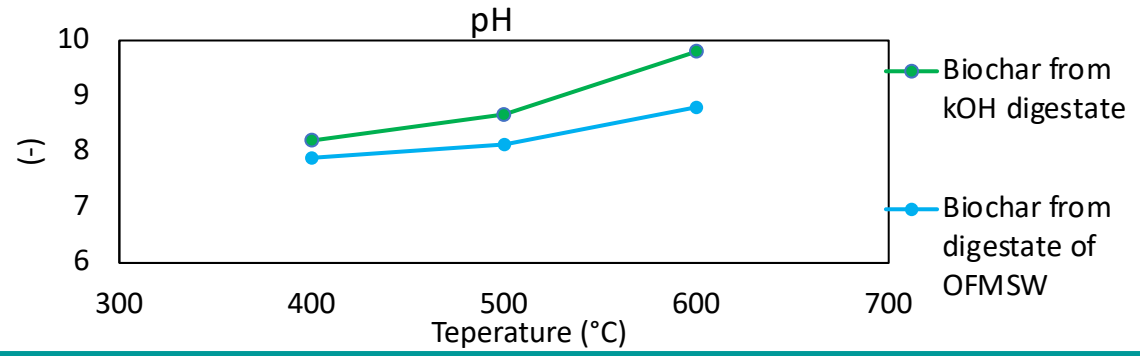


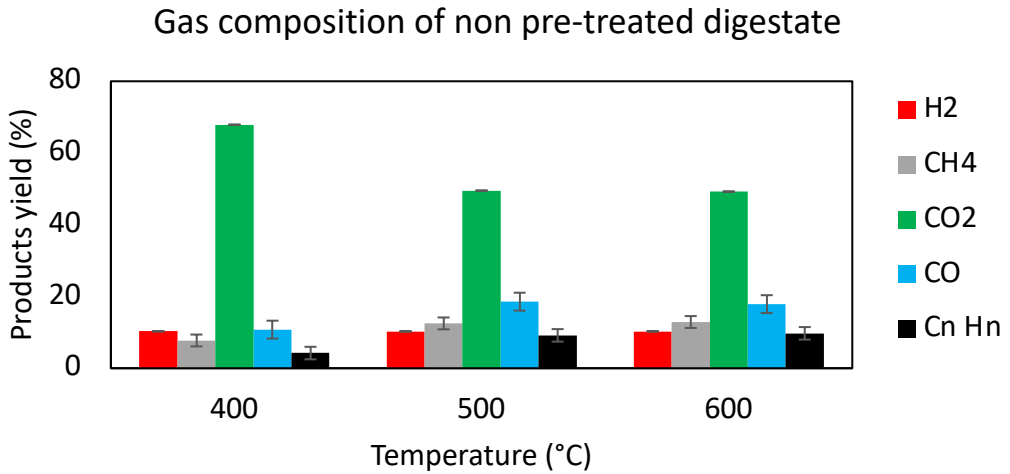



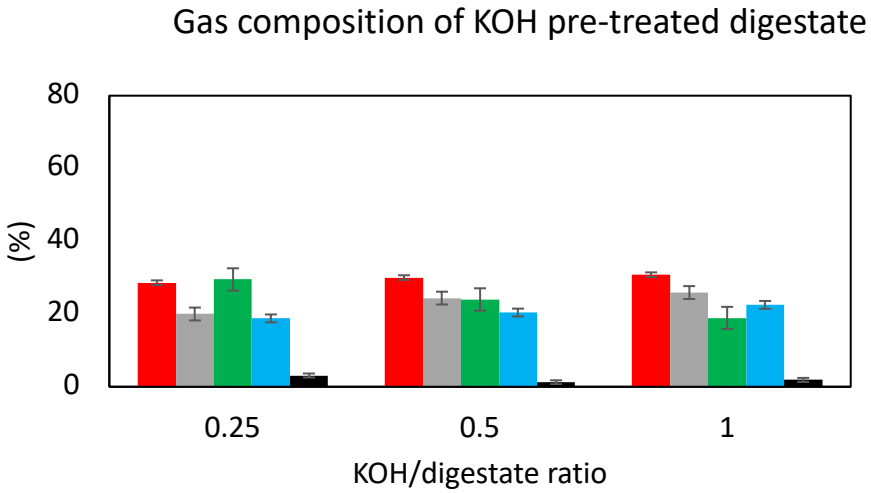



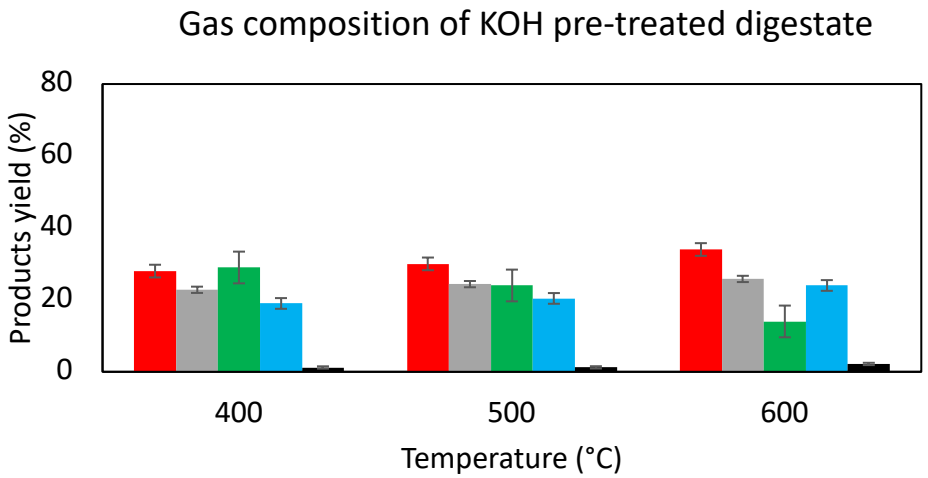



# Slow pyrolysis: study of gas composition

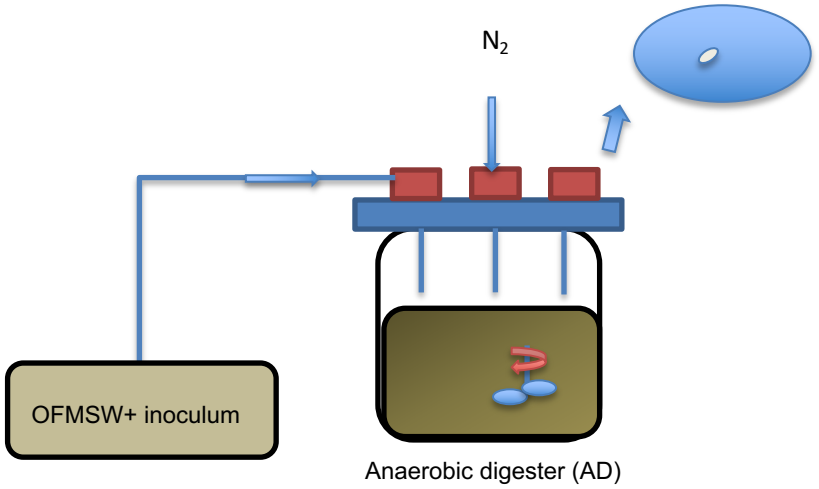


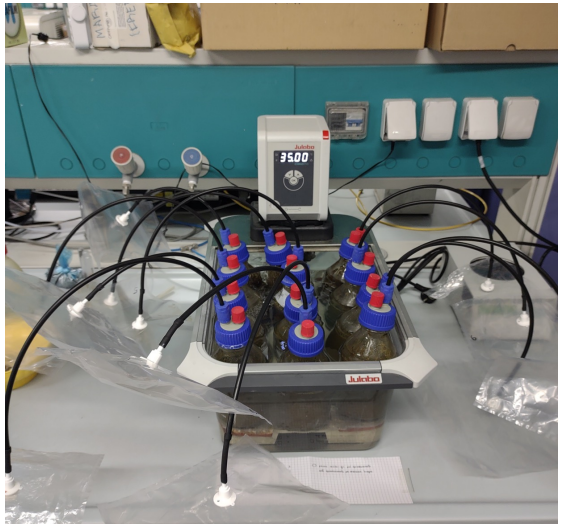



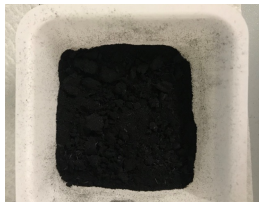
# Anaerobic digestion with biochar: conditions

- Batch mode feed
- TS feed: 6 %
- S: OFMSW (Fossano, Italy)
- I: digestate from cow-agricoltural waste
- S:I = 2:1
- T = 37 °C
- Volume = 500 mL
- **Biochar dose 5 and 10 g/L**:
  - KOH-biochar (BA): KOH/digestate =1:2
  - Biochar from digestate (B)
- Tests in triplicate



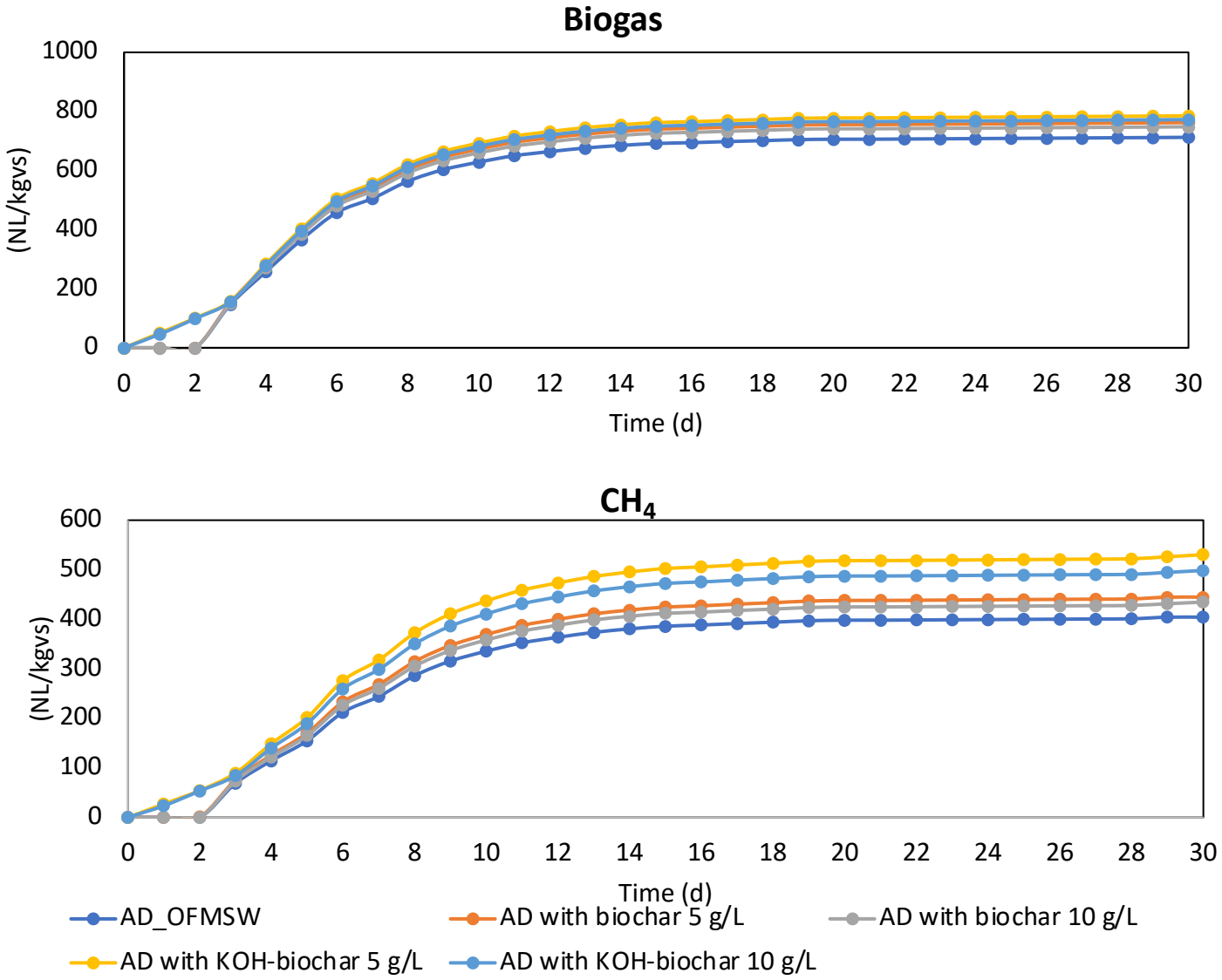
Biochar from KOH-pre-treated digestate



Biochar from digestate

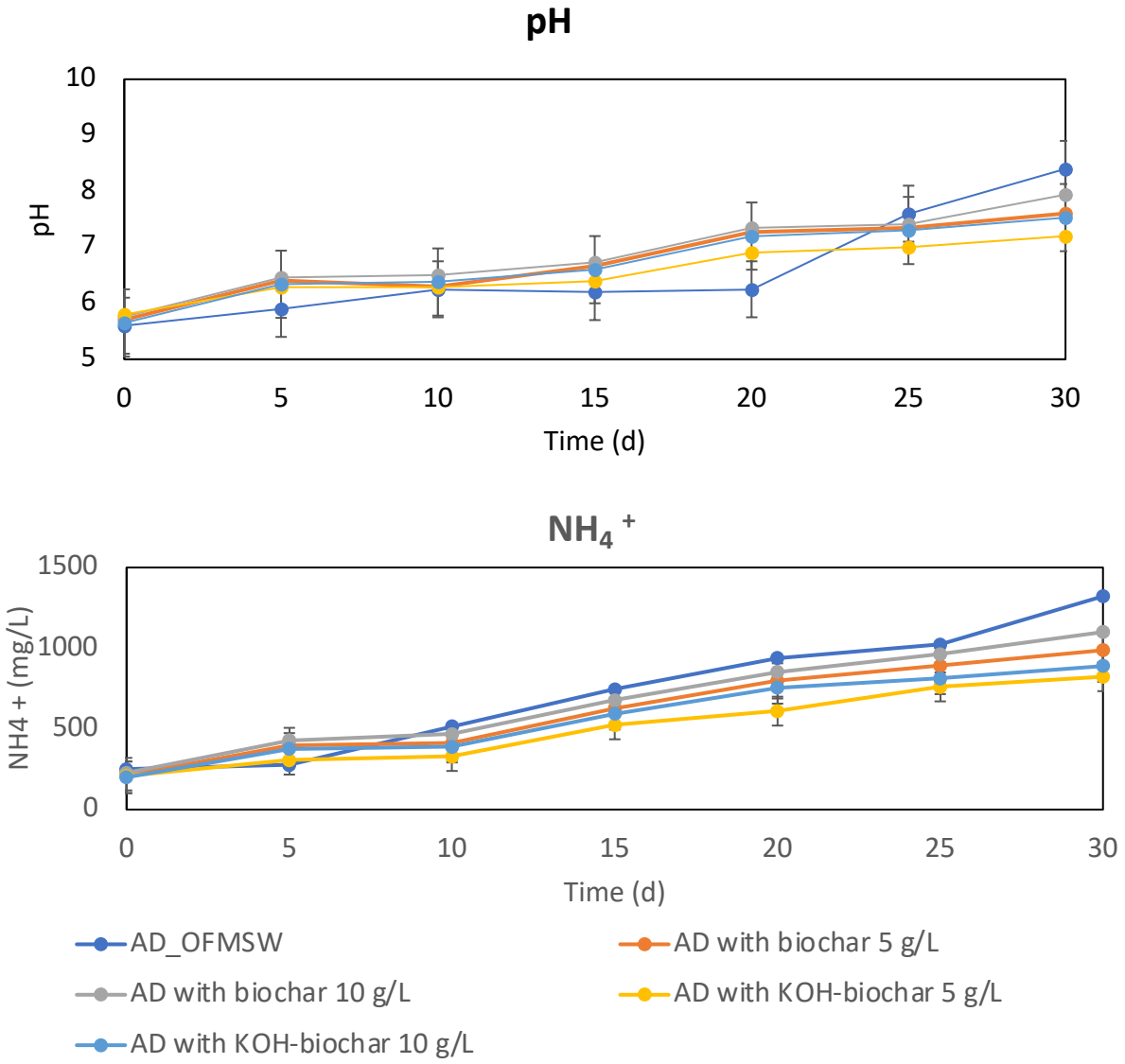
(Ovi et al., 2022) https://doi.org/10.1016/j.fuel.2022.123188

# Anaerobic digestion with biochar: performances



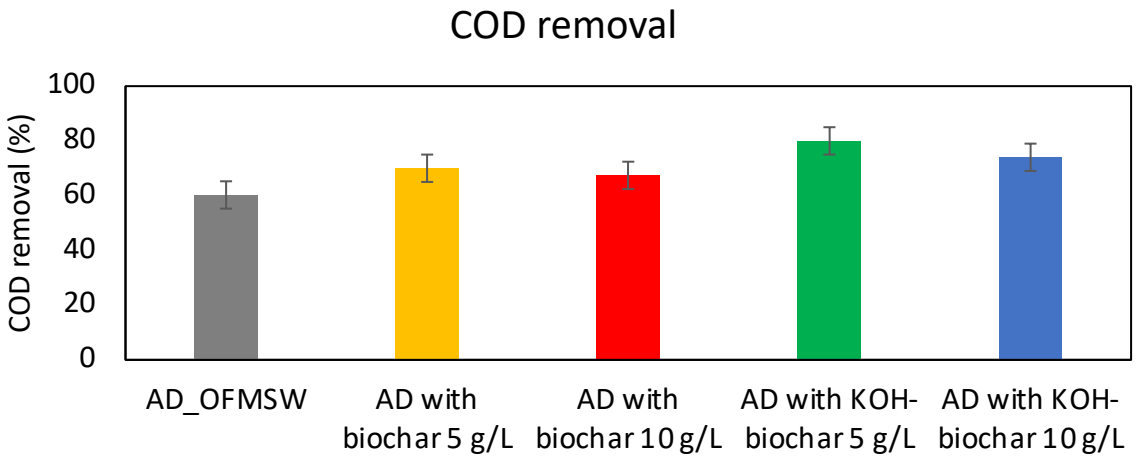

- The biogas yields did not change significantly.
- The $CH_4$ yield increased with the addition of KOH-pre-treated biochar.
- The AD with KOH-pre-treated biochar at 5 g/L reached + 24 % $CH_4$ compared to AD without biochar.
- The dose 5 g/L performed better than 10 g/L

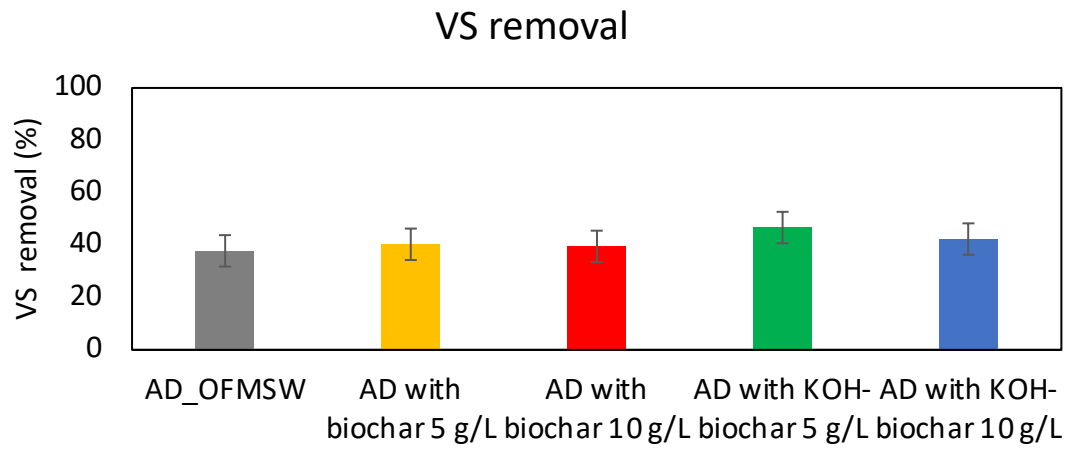
# Anaerobic digestion with biochar performances

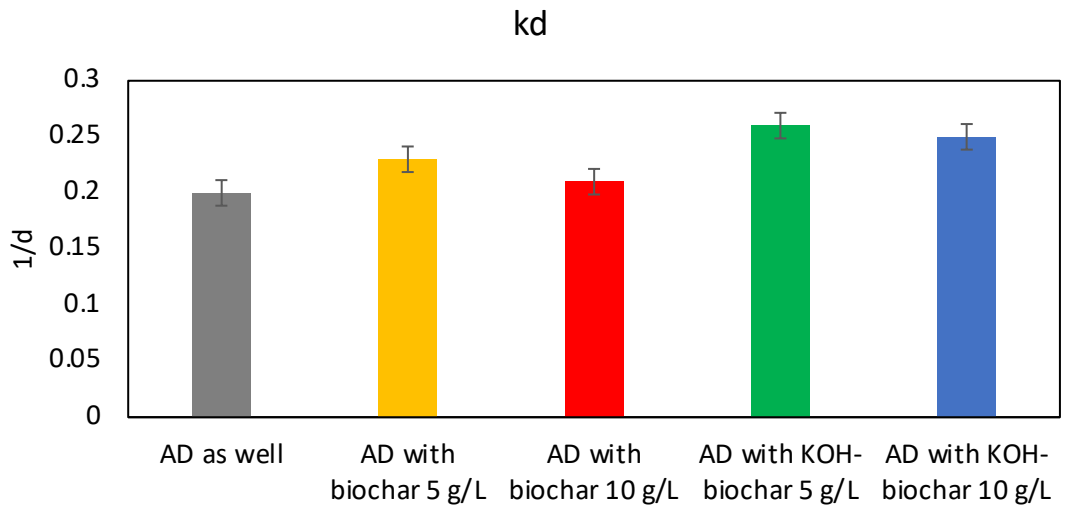



- The addition of biochar keep the pH in the desiderable range for AD : 6.5-8.
- The addition of biochar keep the ammonia concnetration below 1200 mg/L.
- KOH has strong $NH_4^+$/ $NH_3$ adsorption capacity.
- The highest performance was reached by 5 g/L
- KOH-pre-treated biochar has alkaline groups on its surface, which alleviate acid inhibition in the system.

# Anaerobic digestion with biochar performances




- COD degradation and VS removal indicated the microbial behaviour.
- Kinetic disintegration improved with KOH-pre-treated biochar due to the faster biodegradation.

# Conclusions and future perspectives

- KOH-digestate derived biochar reached higher surface area and pore volume by increasing the KOH/digestate ratio and pyrolysis temperature
- The optimal biochar in AD was the biochar derived form digestate pre-treated with KOH at 1:2 ratio at 600 °C at 5 g/L
- The 5 g/L dose of biochar reached higher performance than 10 g/L both with and without KOH pre-treated biochar.
- Environmental analysis will be performed.

# Thank you for the attention

# References


1. Wei Chen, Meng Gong , Kaixu Li , Mingwei Xia, Zhiqun Chen, Haoyu Xiao , Yang Fang , Yingquan Chen Haiping Yang, Hanping Chen. Insight into KOH activation mechanism during biomass pyrolysis: Chemical reactions between O-containing groups and KOH. 2023. Applied Energy 278 (2020) 115730 . https://doi.org/10.1016/j.apenergy.2020.115730
2. Debnath Ovi, Soon Woong Chang, Jonathan W.C. Wong, Davidraj Johnravindar, Sunita Varjani , Jae Hoon Jeung, Woo Jin Chung, Anand Thirupathi, Balasubramani Ravindran. 2022.Effect of rice husk and palm tree-based biochar addition on the anaerobic digestion of food waste/sludge. Fuel 315 (2022) 12318. https://doi.org/10.1016/j.fuel.2022.123188