Hyperthermophilic fermentation (HF) of Food Waste allows the reliable recovery of Volatile Fatty Acids (VFA) by means of stripping.

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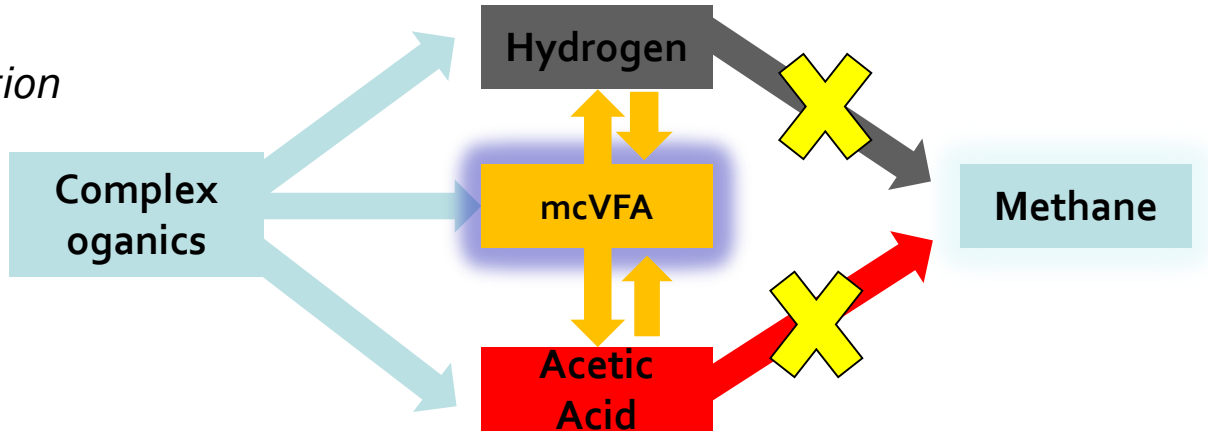
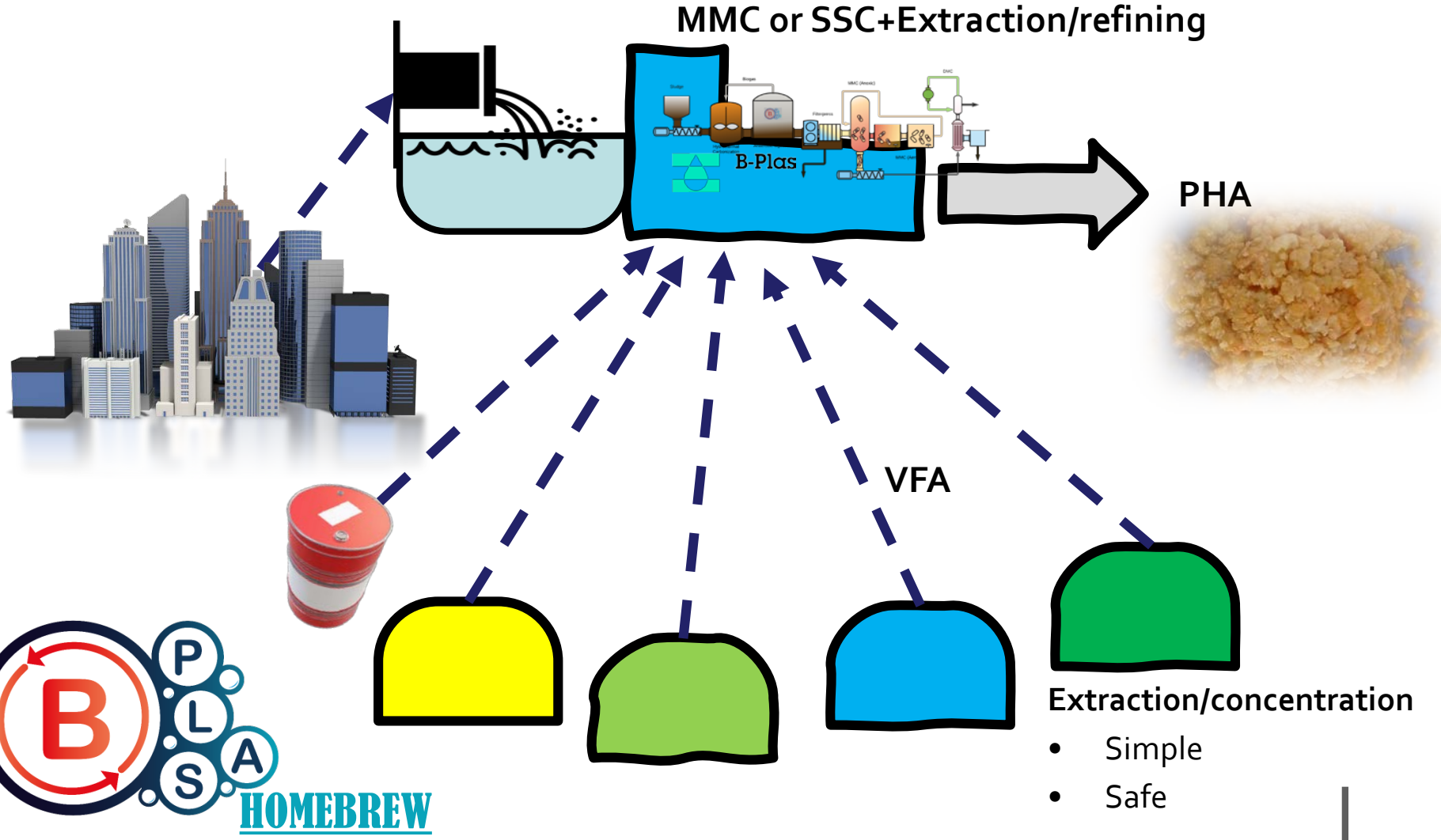
Food Waste to VFA

- Beyond Methane, Volatile Fatty Acids (VFA) are the most thermodynamically stable organic compounds in anaerobic digestion➔ they can be produced with simple and non-sterile MMC
- Acidogenesis and spontaneous pH drop allow to converts food waste into VFA with high volumetric productivity with yield up to 70%
- The main issue is self-inhibition at 2-3% level that intrinsically limits the yield with high COD substrates (>50 gCOD/L)
- Extractive fermentation has been proposed as method to overcome toxicity and within one-step refining of FW into chemicals.

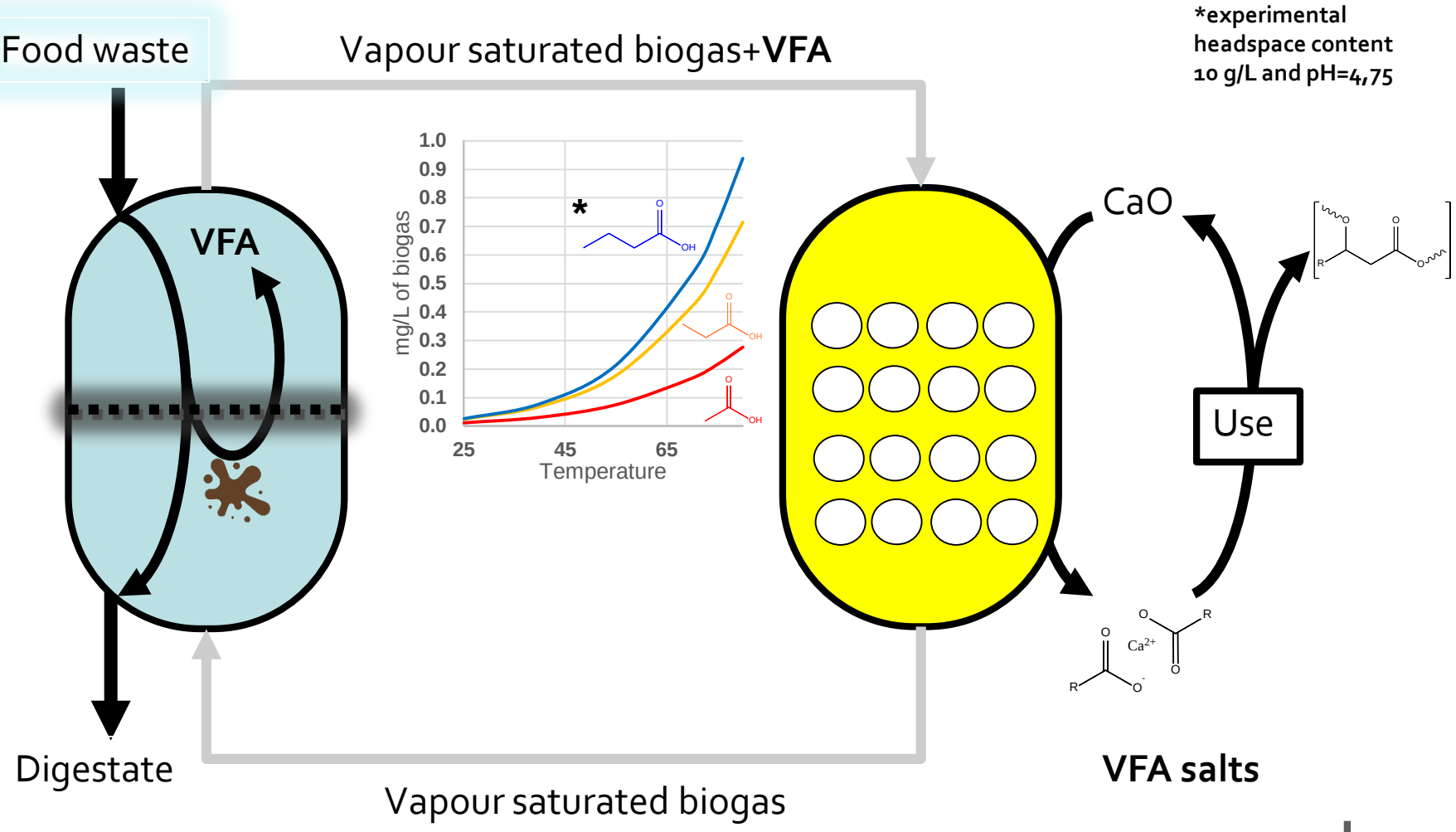
COD Flow
In Anaerobic Digestion



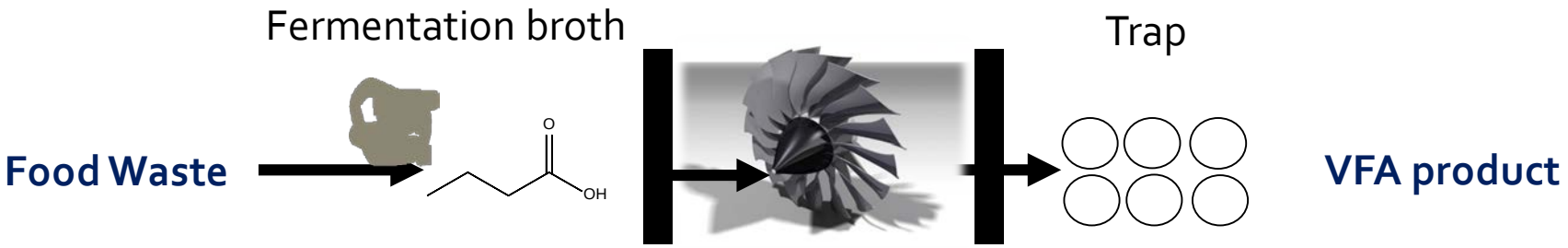
VFA *polygeneration*



VFA stripping

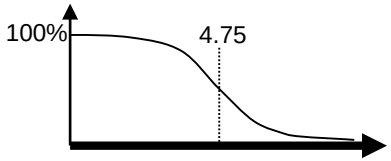


Biogas as solvent

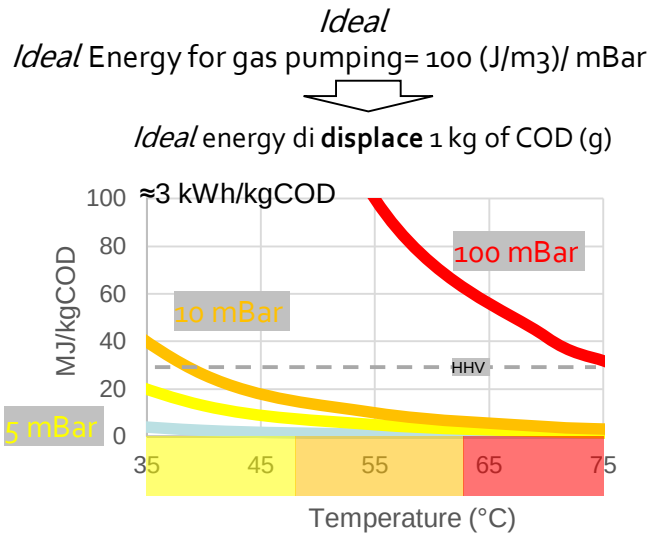


Mass transfer= $K_L a_1 (C_{sat}-C) = Q \cdot C = K_L a_2 C$

- Low cost, losses are not a problem
- Not toxic, no toxic residues in the VFAs.
- Extremely good phase separation due to different density.



- Stripping on Free VFA (pH<5)
- High Henry constant (Low P_v) of VFA at low temperature
- Low mass transfer coefficient unless high power consumption

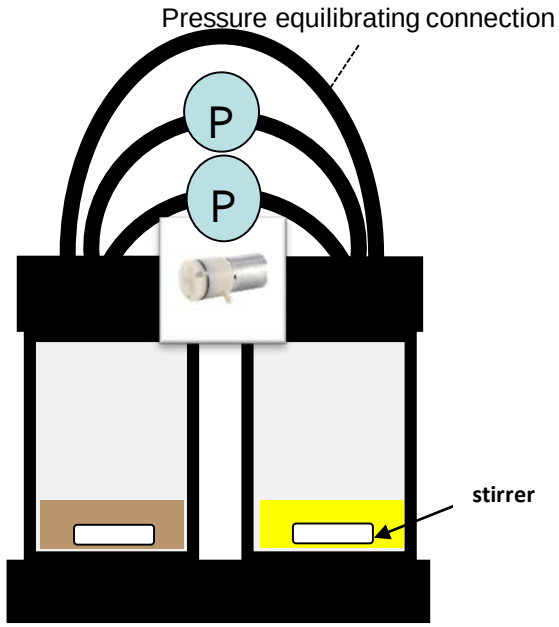


Hyperthemophilic digestion (HT) required for enough VFA in gas without huge gas pumping
High surface area to obtain enough volumetric productivity

Methods setup

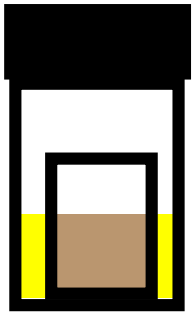
Pump&Mix

- Mechanical pumps
- Mechanical stirring
- 10 g sample
- 5 L/min gas flow
- pH,VFA, COD, reactor-trap



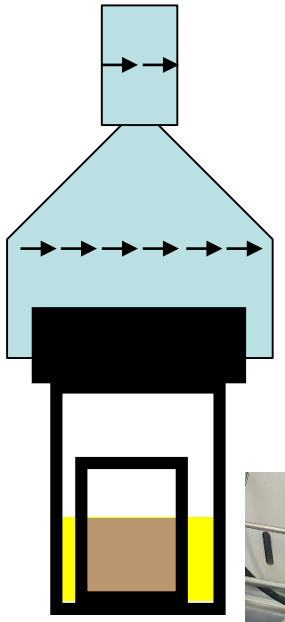
Static

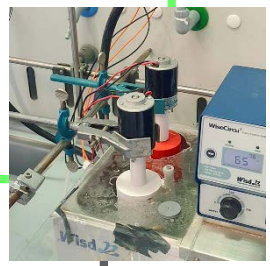
- No mixing
- Gas diffusion
- Diffusion path <u>≤5 cm</u>
- 10 g sample
- pH,VFA, COD, reactor-trap



JB reactor

- Pulsed react. rotation
- Gas diffusion (high)
- Diffusion path <u>≤5 cm</u>
- 10 g sample
- pH,VFA, COD, reactor-trap





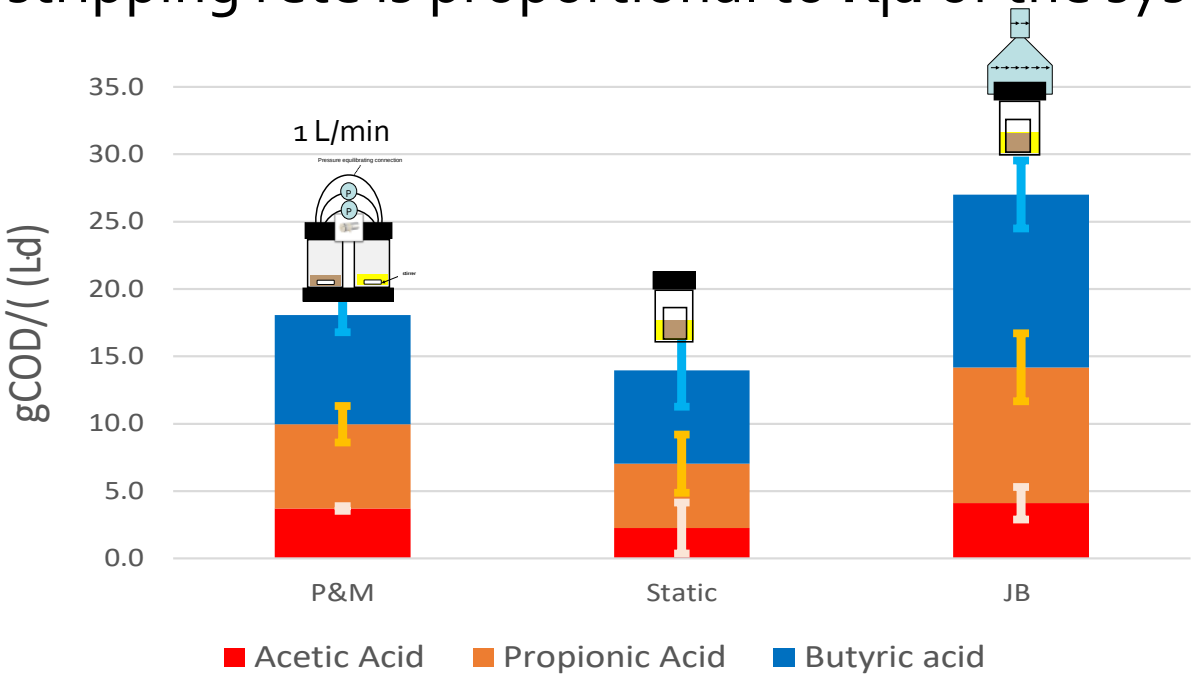
10 g/L VFA
pH=5

1 M NaOH,
CaO or $CaCO_3$

Methods setup: results

Model system, 4 h test

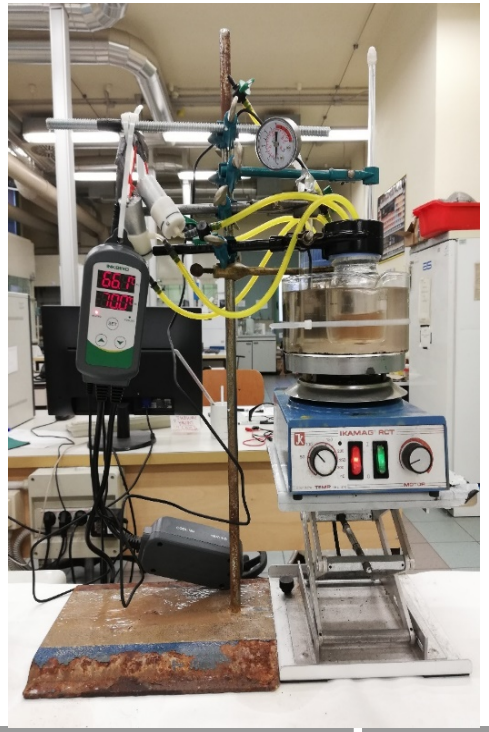
- VFA stripping rate (**gCOD/L d**)
- ➢ **Alkaline Trap** NaOH=CaO=$CaCO_3$
- ➢ The **limiting step** is VFA(aq)➔VFA(g)
- ➢ VFA stripping rete is proportional to **K_la** of the system.



Extractive fermentation test

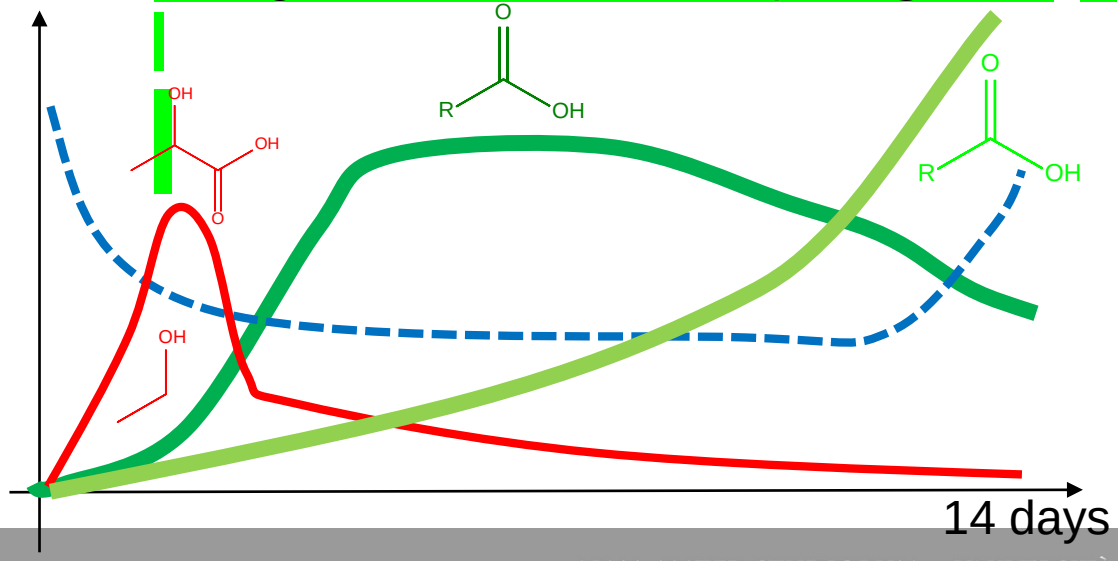
- Acclimatization/bioagumentation of HT inoculum at 55-65°C from commercial thermophilic digesters (corn silage+sewage sludge mixed inocula+ 5% Glucose 2 week)➔Methane producing HT inoculum
- Homogeneous FW sample with composition in line with that of literature (Strazzera *et al.* 2018)
- Test performed at 65°C with 9 g FW+ 1 g inoculum (high substrate/Inoculum ratio)

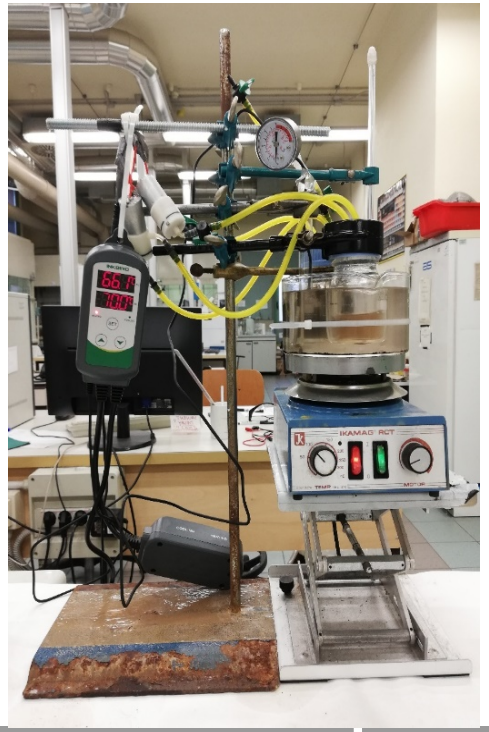
	Avg	St. Dev (n=5)
COD (gO/gWet)	224	±3,00
sCOD (gO/gWet)	115	±2,00
N	1,2	±0,05
C	41	±1,21
H	6,5	±0,18
S	-	-
O	48	±1,32
ash	3,8	±0,10
C/N	38	±1,20
Lipids	32,9	±0,02
Carbohydrates	53,7	±0,01
Proteins	7,6	±0,36



Extractive fermentation test

- **Initial phase➔** production of lactic acid, ethanol and VFA and pH drop to <5.2
- After 3 days, dynamic equilibrium is reached with 10-20 **10-20 g/L of VFA**.
- >3 days, constant broth composition with progressive VFA stripping.
- <5% (COD/COD_{in}) methane and hydrogen generation.
- Stripping is the rate limiting step until the exhaustion of the process.
- Extraction overcome the 3% barrier (145 $gCOD_{VFA}/kg$)
- **65% VFA** yield higher than non-extractive HT fermentation
- Average Volumetric Productivity ≈ **10 gCOD L^{-1} d^{-1}**





Conclusions

Qualitative facts

- Hyperthermophilic fermentation with mixed sludge inoculum easily achieved in one week (ubiquitous microorganisms?)
- First Analytical system to evaluate acidogenesis yield beyond product inhibition (e.g. bio-acidification test)
- With selective removal of Volatile Fatty Acids➔ butyric acid is the main fermentation products

Quantitative Performances

- Even at acidic pH (pH<5) >80% FW solubilization, **65% VFA** yield in 14 days .
- Achieved maximum **>10 gCOD/L** d Volumetric productivity ($K_La \approx 30\ h^{-1}$) mainly related to gas-liquid exchange between fermentation broth and biogas.
- Average concentration in biogas at **60% of saturation** (≈1 gCOD/m^3)
- Estimated Gas pumping Energy ➔**1-3 MJ/kgCOD** at 10 mBar Pr. Drop.

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