2–4 July 2015:
3rd INTERNATIONAL CONFERENCE on
Sustainable Solid Waste Management,
Tinos island, Greece

Impact of thermal pre-treatment of food wastes on anaerobic digestion performances

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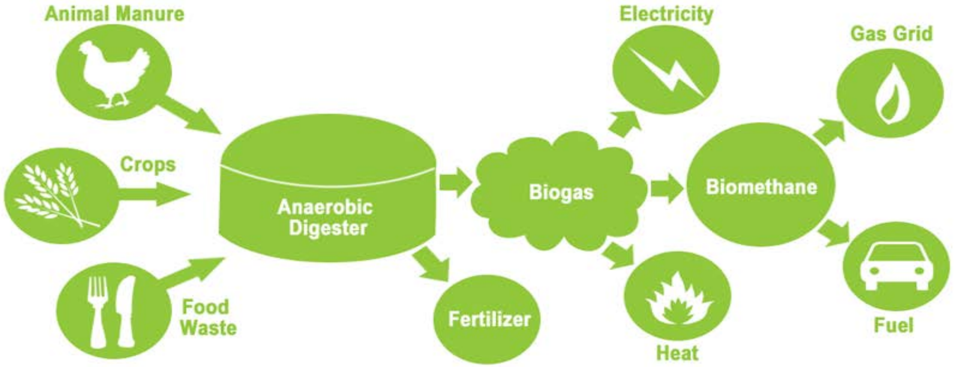
- 100 million tonnes of Food Waste is generated annually only in Europe (agri-food waste and fish discards not included!)

- Quantities are going to be rising in the next few years, severely affecting the global warming contribution of landfilled Food Waste

The substrate is definitely <u>suitable</u> for ANAEROBIC DIGESTION:

- High biodegradability
- Elevated water content and bio-methanation potential



Our GOALS were:

1. Accurate chemical characterization (as regards soluble and particulate fraction) of a complex substrate as food waste;

2. Evaluation of thermal pretreatment efficiency, in terms of solubilization extent;

3. Assessment of the effect of pretreatment on digestion performances (under mesophilic and thermophilic conditions);

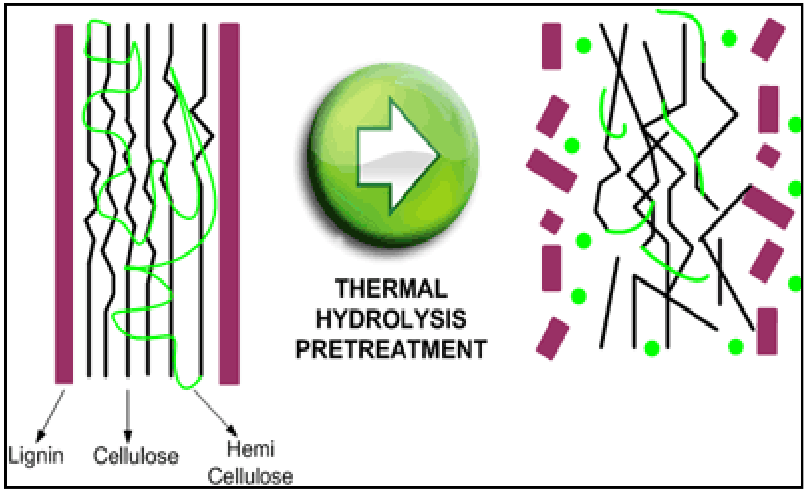
4. Future scale up to semi-continuous anaerobic reactor system.

Thermal pretreatment

Accelerate the hydrolysis step (complex organic matter, such as proteins, lipids and carbohydrates, are transformed in simple soluble matter, like aminoacids, sugars and fatty acids);

Improve the accessibility of biodegradable compounds.

Thermal pretreatment



In the first phase, the biowaste is treated with saturated steam at high temperature and pressure.

In the second phase, the pressure is drastically reduced down to P_{atm} causing the cleavage of chemical bonds among the polymer components of biowaste.

Cafeteria food waste

Mechanical pretreatment

Cafeteria food waste

Thermal pretreatment

Dilution to 10-15% TS
before autoclave treatment

After autoclave treatment

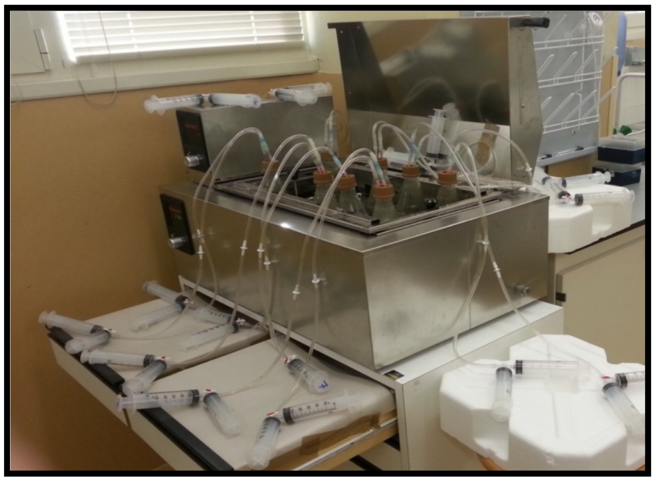
Characterization and comparison

	CNR Cafeteria FW	References
pH	4.5	4.41-5.2
TS (g/L)	113-130	70-197
VS (g/L)	107-124	60-170
TS/VS (%)	95-97	87-96
COD sol (g/L)	34.5-70.2	11-75
COD tot (g/L)	114-184	110-238
Proteins sol (gCOD/L)	13-14	n.a.
Carbohydrates sol (gCOD/L)	17-26	6
N tot (g/L)	2.6-3.7	5.1-7.4

Effect of pretreatment on the soluble fraction

	Untreated FW	Pretreated FW
COD (g/L)	34-70	69-98
Proteins (gCOD/L)	13-14	16-19
Carbohydrates (gCOD/L)	17-26	24-44

Biochemical Methane Potential (BMP) tests

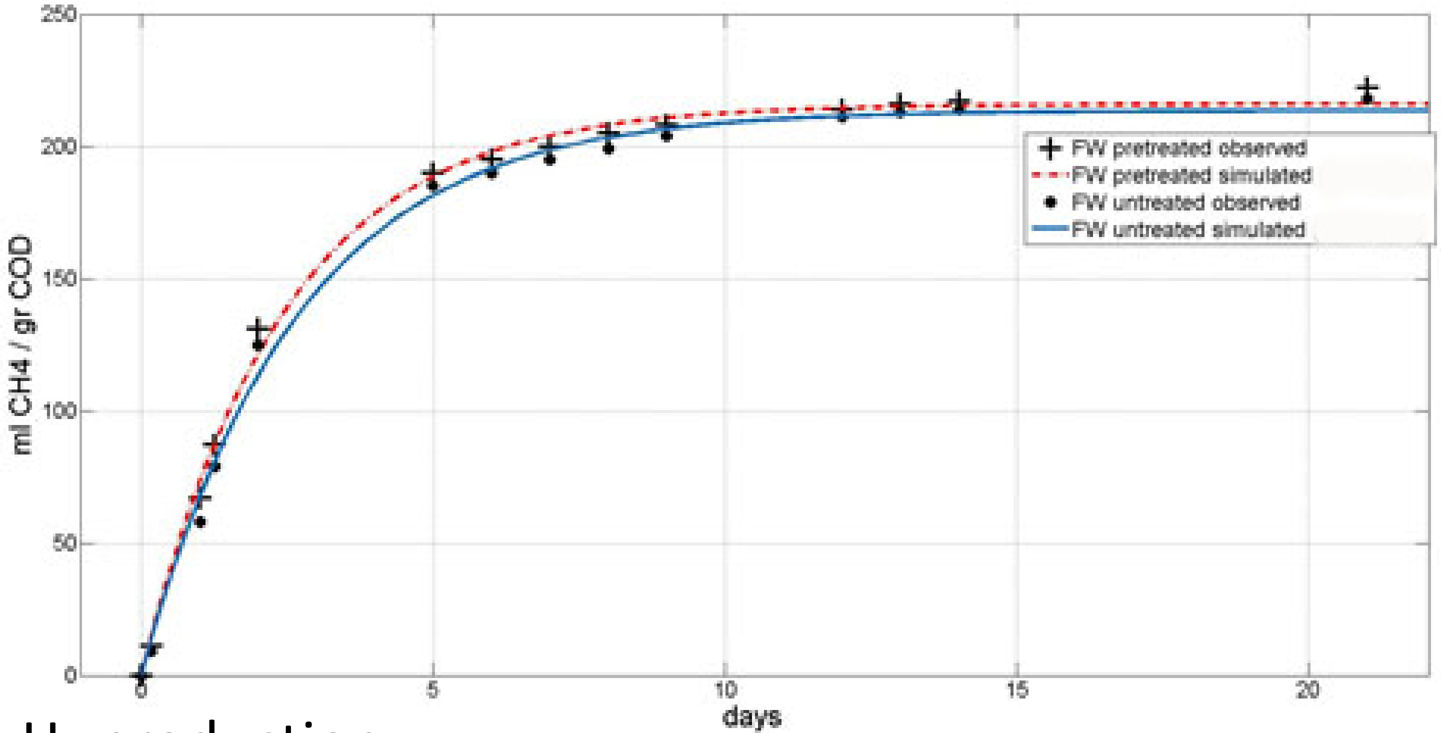


- ✓ Mesophilic/thermophilic conditions (37˚C/55° C)
- ✓ Test duration: 20-30 days
- ✓ Working volume: 0.3 L
- ✓ Mesophilic/thermophilic digested sludge as inoculum
- ✓ Pretreatment conditions: T_{max}=134° C; P_{max}=312KPa; t=20min
- ✓ F/I=0.6
- ✓ H_2 and CH_4 monitoring

- ✓ 2 *<u>mesophilic</u>* BMP tests adopting the same operating conditions (F/I=0.6) except for initial pH treating both untreated and pretreated substrates
  - #1: FW, pH_i=8.0 meso
  - #2: FW, pH_i=7.0 meso
- ✓ 2 *<u>termophilic</u>* BMP tests adopting the same operating conditions (F/I=0.6) except for initial pH treating both untreated and pretreated substrates
  - #3: FW, pH_i=8.0 thermo
  - #4: FW, pH_i=7.0 thermo

#1: FW mesophilic pH8 BMP test

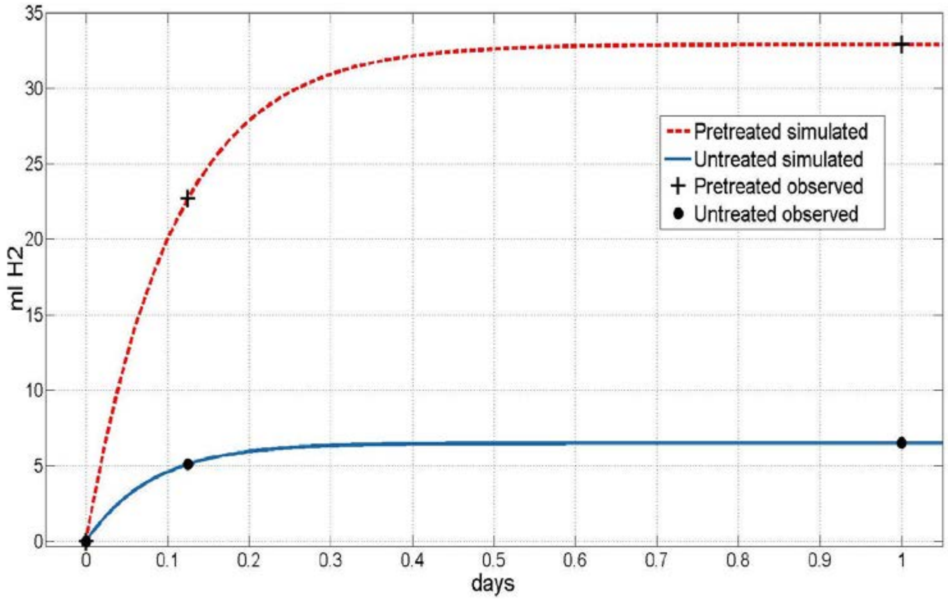
Methane yield under mesophilic conditions



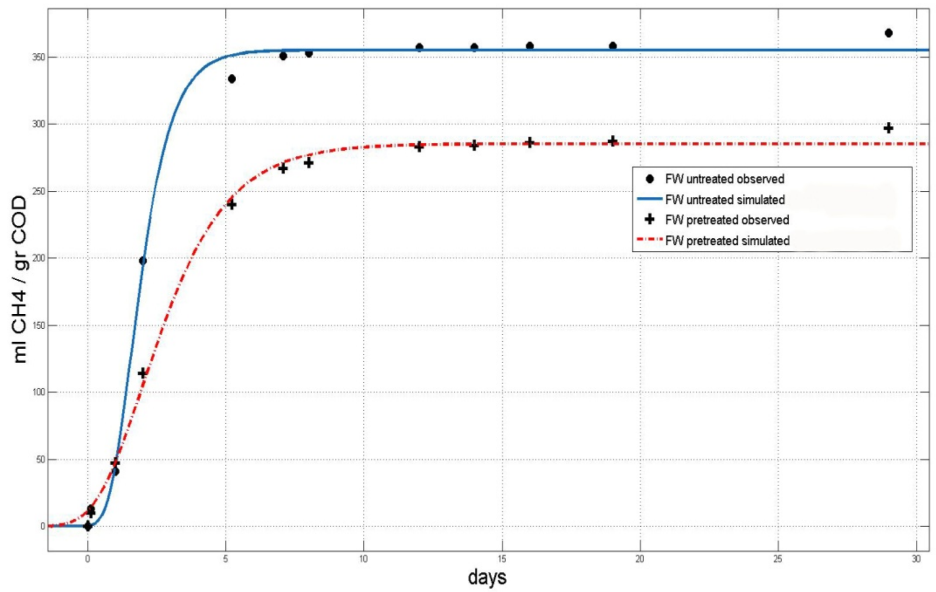
- ✓ No H_2 production
- ✓ No difference in final cumulative methane production between Untreated and Pretreated samples

#2: FW mesophilic pH7 BMP test

Hydrogen production under mesophilic conditions

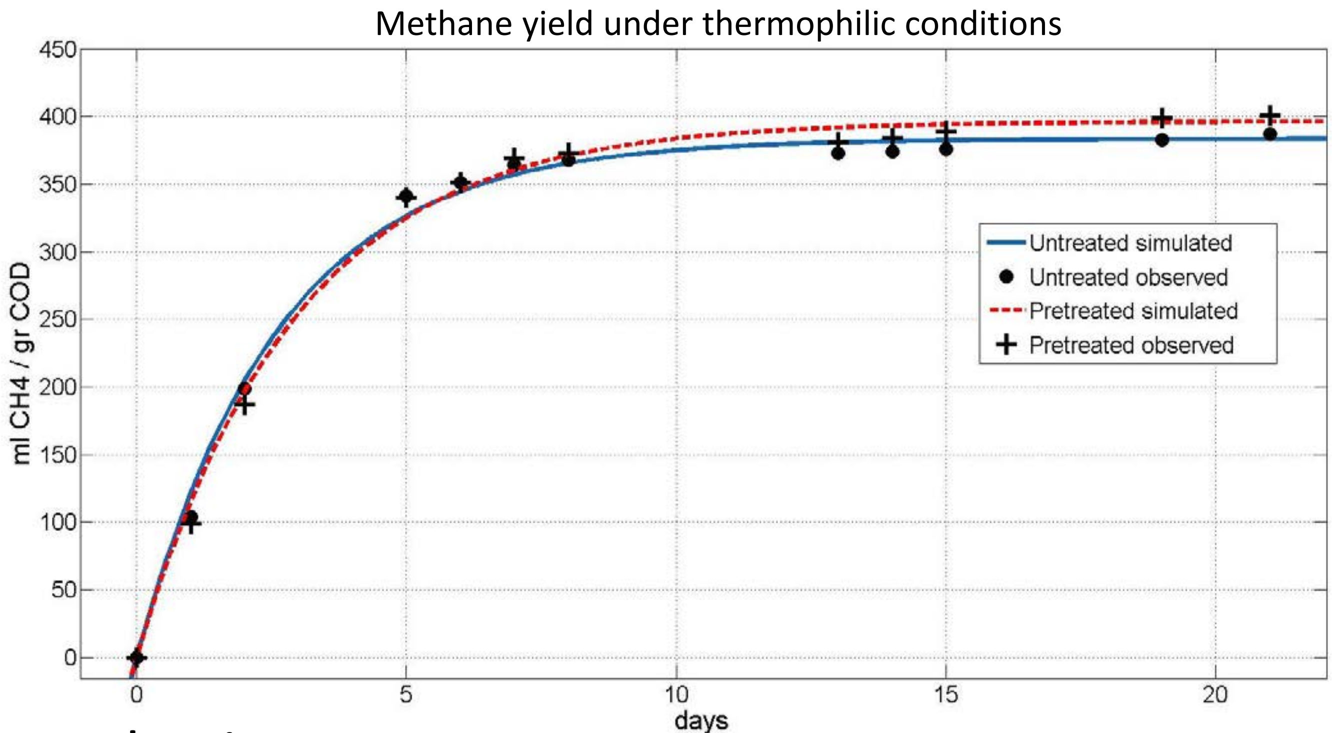


Methane yield under mesophilic conditions



- ✓ Initial pH correction (pH_i=7.0) ➔ H_2 production was detected
- ✓ Pretreatment affected the quantity of hydrogen produced
- ✓ Untreated mixture showed higher specific methane yield, probably due to the difference in hydrogen production

#3: FW thermophilic pH8 BMP test



- ✓ No H_2 production
- ✓ No difference in final cumulative methane production between Untreated and Pretreated samples
- ✓ T affected positively specific methane yields

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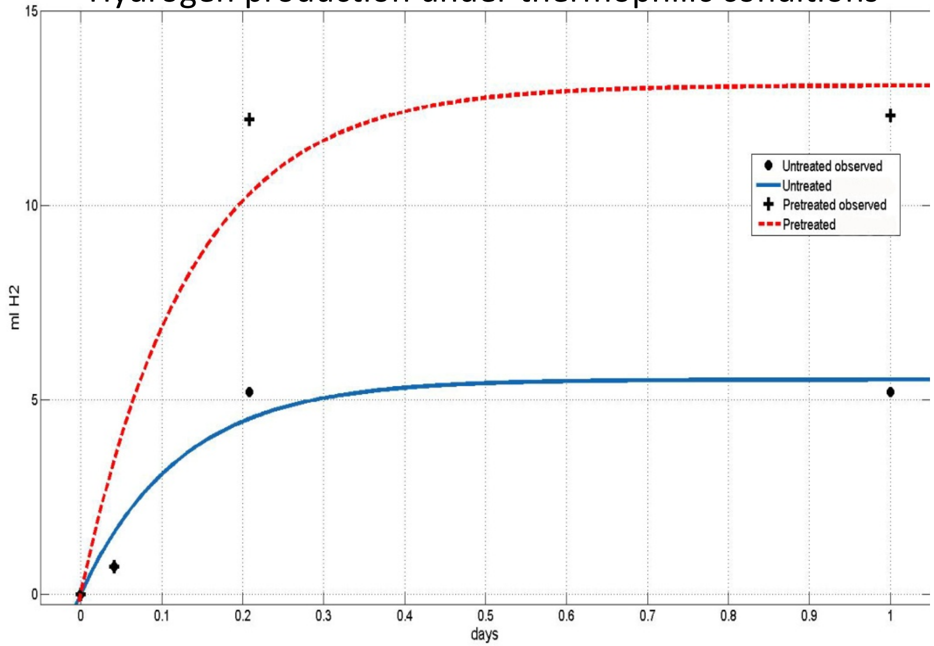
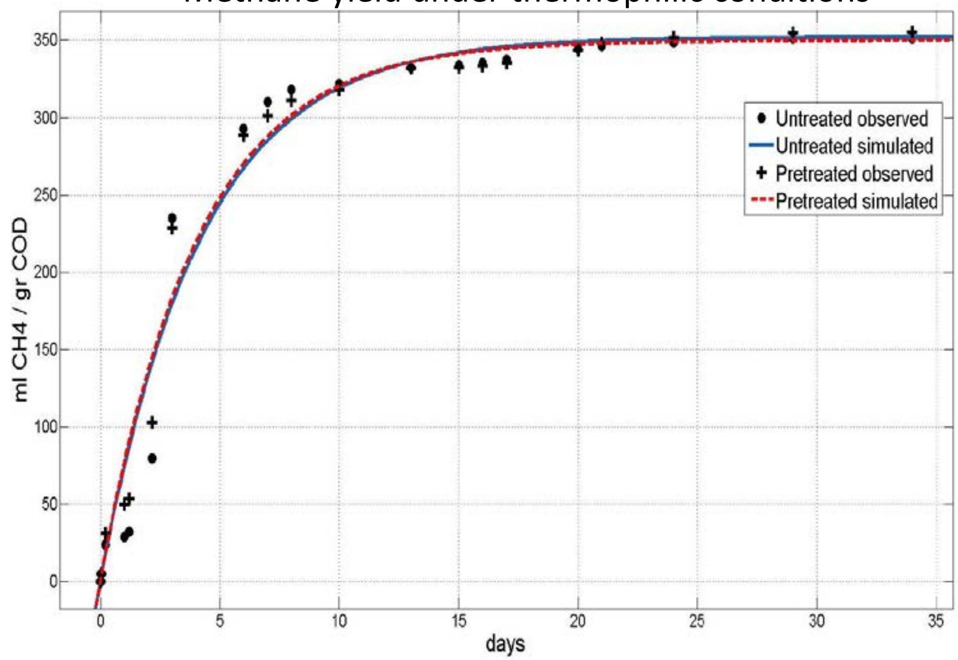
#4: FW thermophilic pH7 BMP test

Hydrogen production under thermophilic conditions

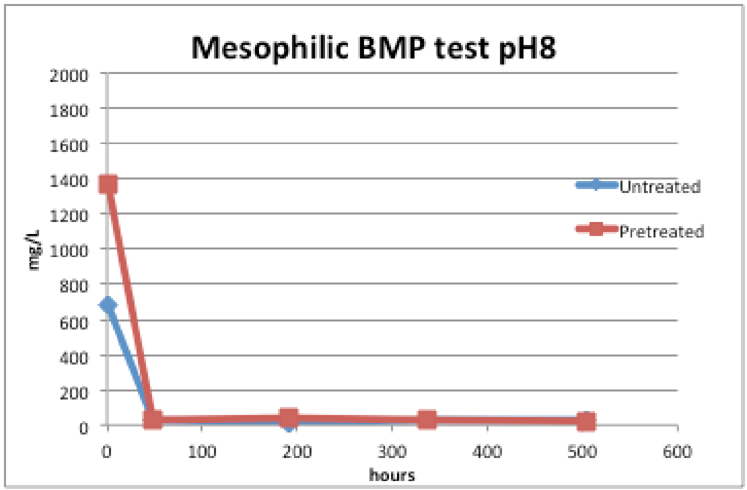


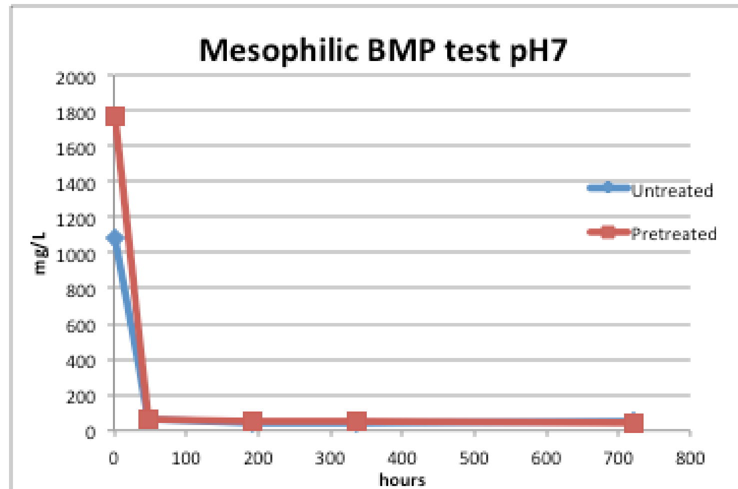
Methane yield under thermophilic conditions

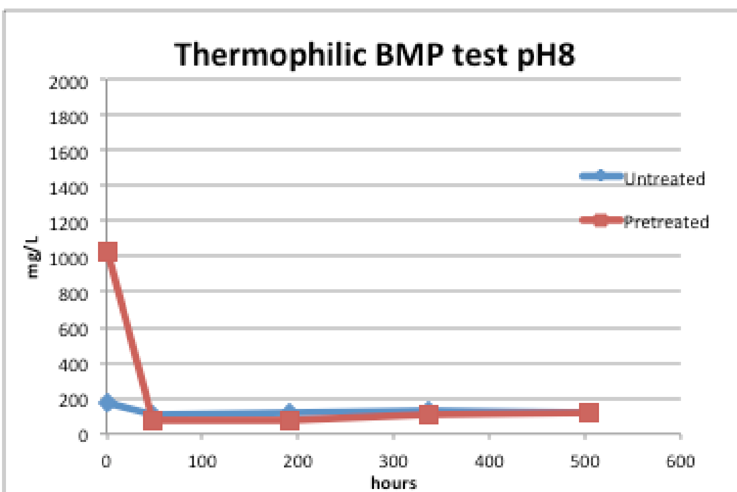


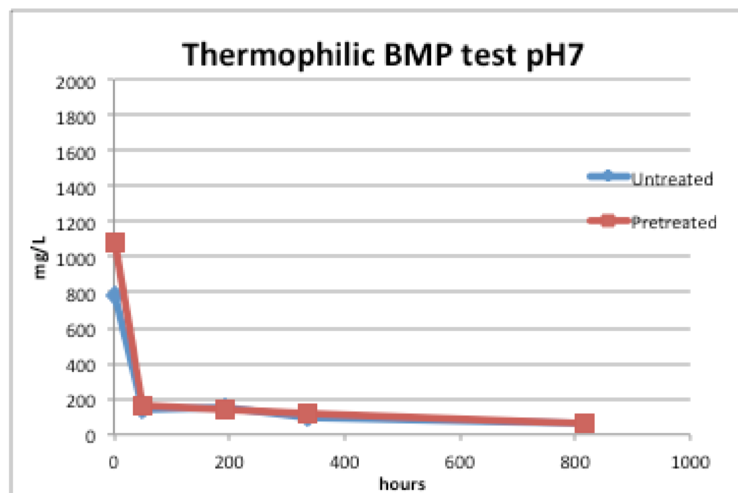
- ✓ Initial pH correction (pH_i=7.0) ➔ H_2 production was detected
- ✓ Pretreatment affected the quantity of hydrogen produced
- ✓ T had a beneficial effect on pretreated mix specific methane yield, levelling out the difference between untreated and pretreated samples

Soluble carbohydrates trend









Performances comparison

	Meso pH8		Meso pH7		Thermo pH8		Thermo pH7	
	Untr	Pretr	Untr	Pretr	Untr	Pretr	Untr	Pretr
VS reduction (%)	34.4	33.5	35.4	35.0	38.2	41.6	38.3	40.1
Biogas yield (mL/gVSfed)	574	589	784	774	1000	908	987	1075
Methane yield (mL/gVSfed)	339	345	445	385	449	409	389	414
Methane content in biogas (%)	59.1	58.5	49.5	44.4	42.2	45.6	37.3	36.8
Hydrogen yield (mL/gVSfed)	-		5	23	-	-	3	7

Conclusions

- ✓ Pretreatment was effective in solubilizing organic matter in particular carbohydrates
- ✓ Pretreatment was efficient in increasing hydrogen production, but the effect was not significant for biogas and methane production
- ✓ In order to enhance hydrogen production, it is necessary to start from a lower pH than the one suggested by some authors (pHi=7.0)
- ✓ Higher digestion T had a positive contribution to biogas and methane conversion rates

Thanks for the attention

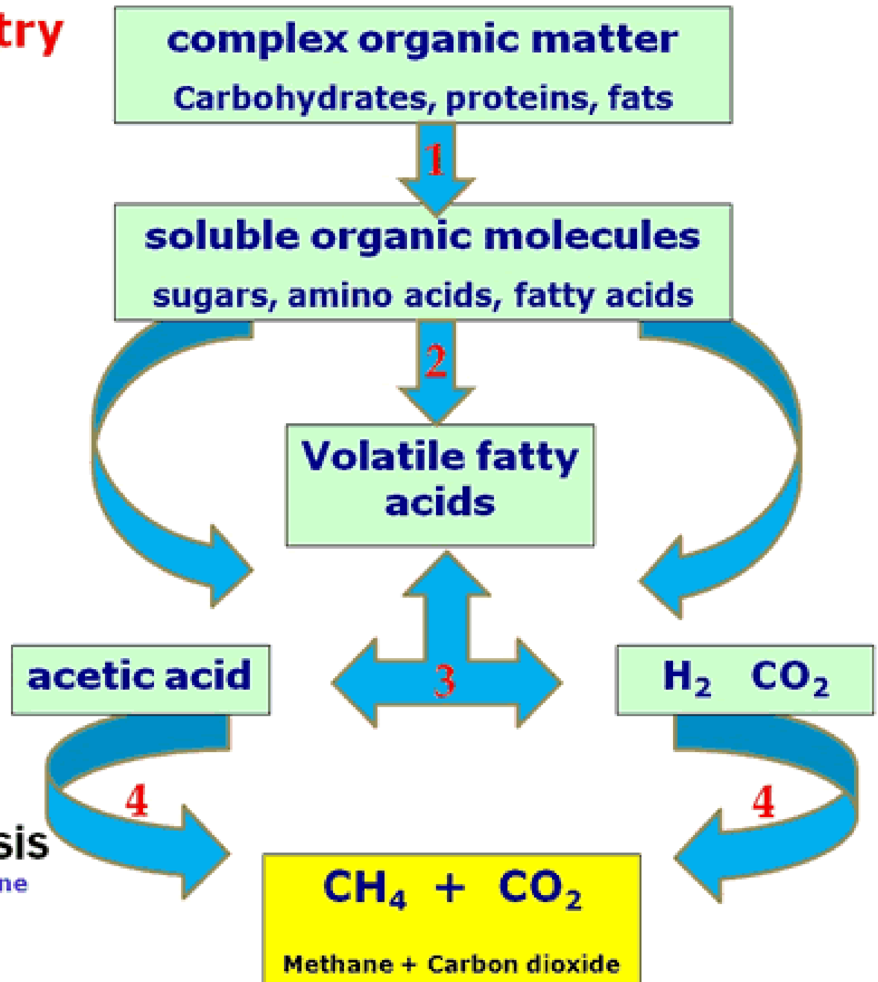
The Biochemistry

1 Hydrolysis
Complex organic molecules to soluble

2 Acidogenesis
Small organic molecules to fatty acids

3 Acetogenesis
Conversion to acetic acid & CO_2

4 Methanogenesis
Final conversion to methane [CH_4]



Gompertz data fitting

Kinetic parameters estimation can be performed by assuming that the overall process is represented by a first order hydrolysis model (Eq. 1):

$$\frac{dS}{dt} = -K_h S \qquad (1)$$

where S is the substrate concentration and K_h is the first order hydrolysis constant.
Once Eq. 1 is integrated, the relationship between substrate concentration and time can be represented by the Gompertz equation (Eq. 2):

$$S = So\ (1\text{-}exp\ (K_h\ t)) \qquad (2)$$

where S_o is the ultimate methane potential.

Modified dubois method

- fructose solution used for calibration
-concentrated H_2SO_4 (1 mL) is added to the sample (200 mL) in a glass tube;
-mixing solution by vortexing 20 sec long;
-waiting until room temperature of the solution is reached;
-then addition of 200 mL of phenol solution (5%) and again the tubes are vortexed
-leave the tubes 3 h in the dark at room temperature

→→ carbohydrates react with phenol and sulfuric acid to give a stable yellow-orange chromogen: the absorbance of standards and samples is determined spectrophotometrically at 480-490 nm

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