Anaerobic digestion of microalgae: evaluation of process performances using ADM1

Francis Mairet*, — Olivier Bernard* — Monique Ras*** — Laurent Lardon*** —Jean-Philippe Steyer*****

*** BIOCORE, INRIA Sophia Antipolis.**

**** Departamento de Matemática, Universidad Técnica Federico Santa María, Chile.**

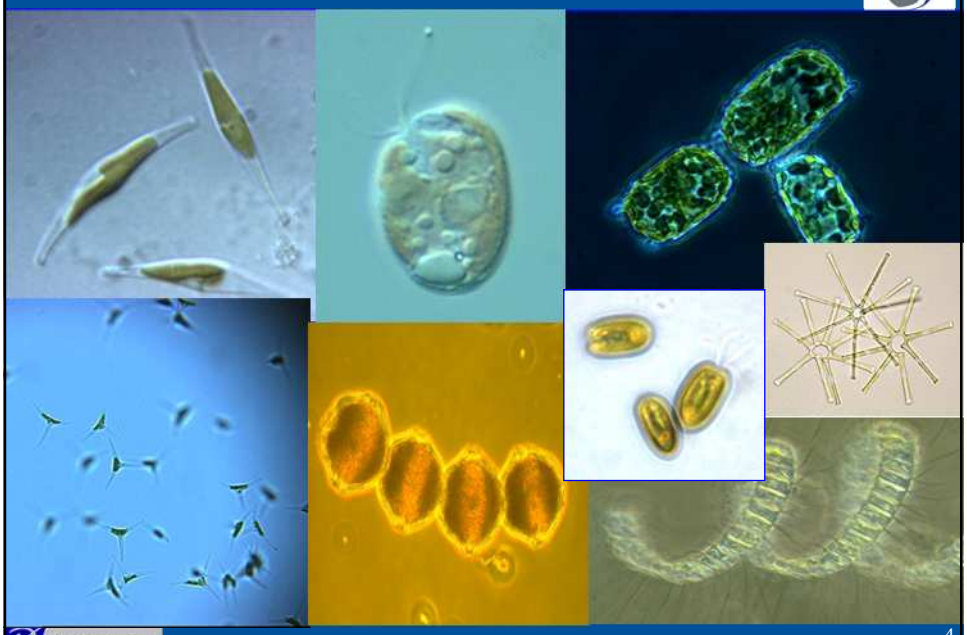
***** INRA, UR050, Laboratoire de Biotechnologie de l'Environnement**

Program

- I – Introduction: What are microalgae?
- II - Modeling anaerobic digestion of microalgae with ADM1
- III - Estimation of process performances
- IV - Conclusion and perspectives

I – Introduction: what are microalgae?

Microalgae: a huge biodiversity



Introduction : microalgae

– They are microscopic. Their size range from 2 to 50 microns

– They can grow very rapidly : generally biomass is doubled every day

– The number of microalgae species is estimated between 200 000 to 1 000 000

Microalgae: they grow everywhere

They develop at large scale

Red tide with the Dinoflagellate *Noctiluca scintillans*

They are cultivated in raceways

Innovalg, France

They are cultivated in photobioreactors (PBR)

(Germany)

- 1 ha
- 700 m³
- 500 km of tubes
- 150 tons per year
- 25 €/kg

They are cultivated (~10 0000 tons per year)

Fish food

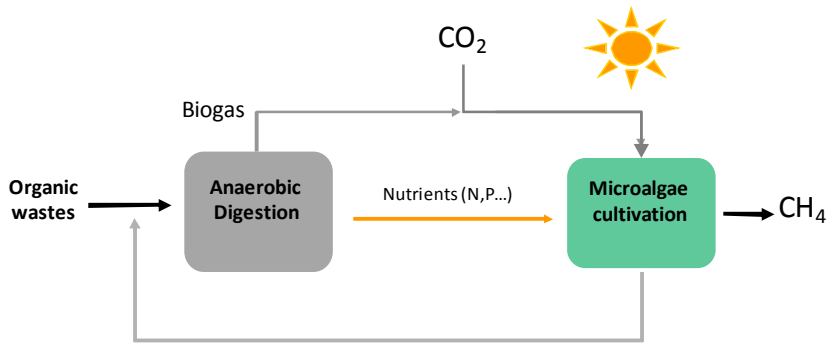
Nutraceutics

Cosmetics

Health

Biofuel and CO_2 mitigation

Focus on the ANR-Symbiose project



- Flue gas and Organic waste treatment
- Need for external inputs decreased
- Solar energy recovery

Bottlenecks of anaerobic digestion of microalgae

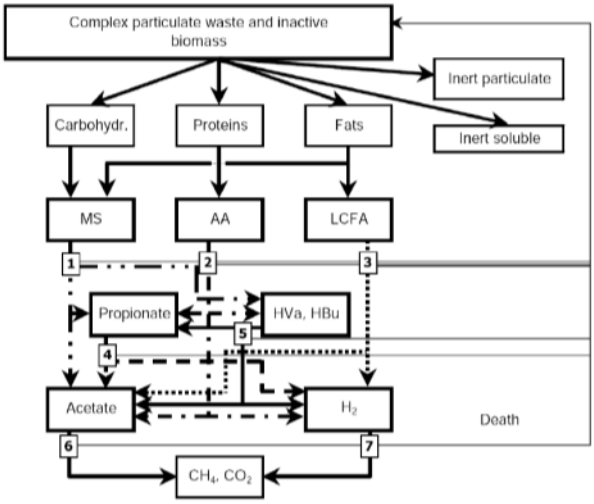
- Main identified limitations in AD
  - High proteins content (NH_3 issue)
  - Cell wall resistance and cell survival
  - Sodium toxicity for marine species

- Solutions
  - Selection of adapted species
  - Increase C/N Ratio (codigestion or metabolic strategy)
  - Biomass pretreatments

(Sialve et al, Biotechnology Advances 2009)

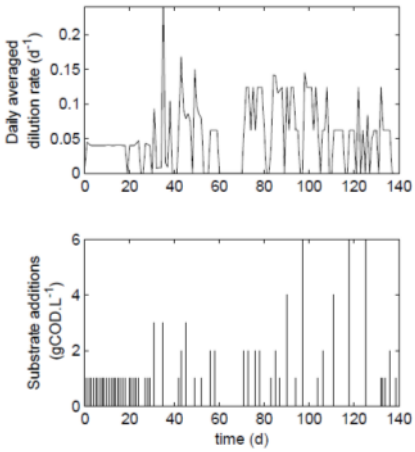
II - Modeling anaerobic digestion of microalgae with ADM1

Recall on ADM1 (Batstone et al, 2002)

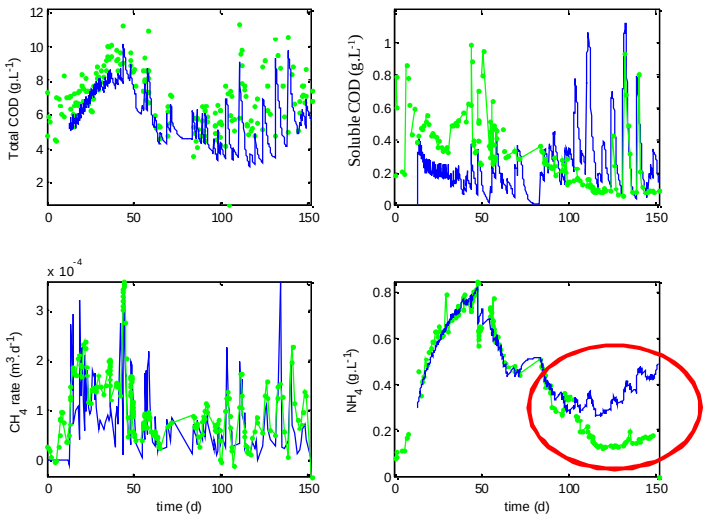


Comparison with experimental data

- Anaerobic digestion of the freshwater microalgae *Chlorella vulgaris* (Ras et al., Bioresource Technology, 2011)
- Data from INRA, UR050, Laboratoire de Biotechnologie de l'Environnement (LBE)



Comparison with experimental data



Modification of ADM1

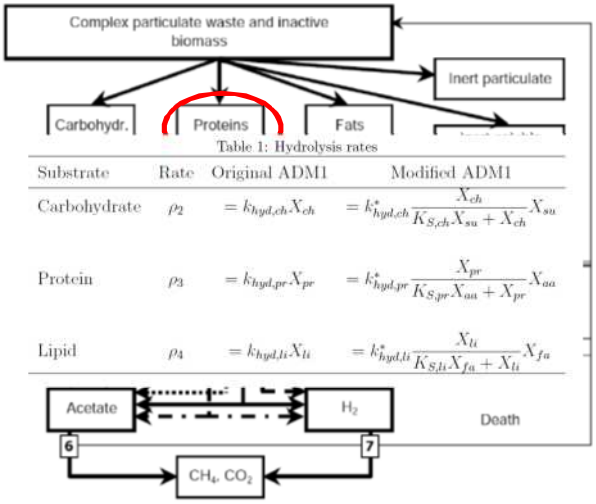


Table 1: Hydrolysis rates

Substrate	Rate	Original ADM1	Modified ADM1
Carbohydrate	ρ_2	$= k_{hyd,ch} X_{ch}$	$= k^*_{hyd,ch} \frac{X_{ch}}{K_{S,ch} X_{su} + X_{ch}} X_{su}$
Protein	ρ_3	$= k_{hyd,pr} X_{pr}$	$= k^*_{hyd,pr} \frac{X_{pr}}{K_{S,pr} X_{aa} + X_{pr}} X_{aa}$
Lipid	ρ_4	$= k_{hyd,li} X_{li}$	$= k^*_{hyd,li} \frac{X_{li}}{K_{S,li} X_{fa} + X_{li}} X_{fa}$

- Low production of NH_4
- Low soluble COD

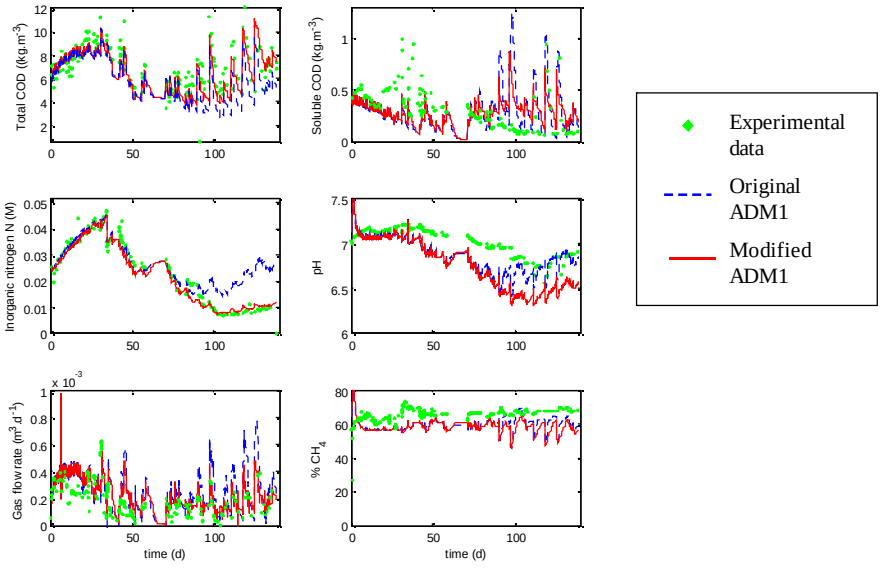
→ Protein accumulation

In ADM1, hydrolyses are represented by first order kinetics.

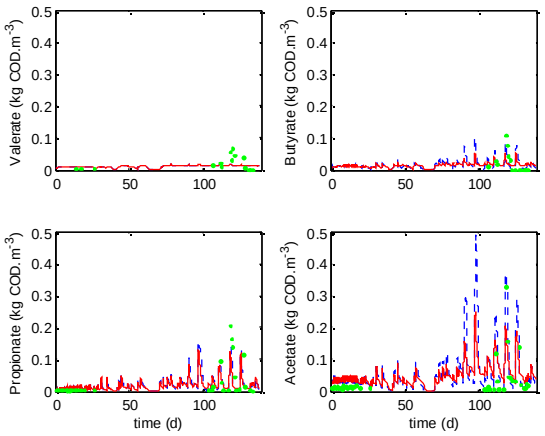
Hydrolysis can be better represented using the Contois model (Vavilin et al., Waste Management, 2008)

→ modification of ADM1

Comparison with experimental data (1)



Comparison with experimental data (2)



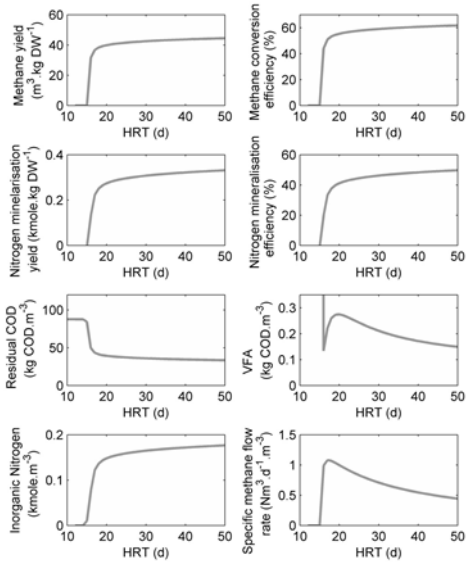
Experimental data

Original ADM1

Modified ADM1

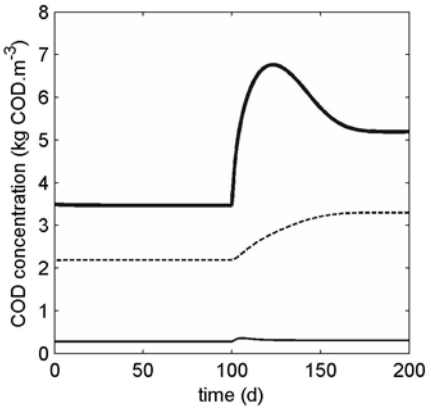
III – Estimation of process performances

Influence of the HRT on the digester performance



- HRT<15d → Reactor acidification
- Optimal HRT ≈ 20 d
- Collet et al. (Bioresource Technology, 2011) with HRT=46 d:
  - methane conversion: 56%
  - nitrogen mineralisation: 90%

Step increases of the input concentration



Soluble substrate
Particulate substrate
Bacterial population

- Hydrolysis is the limiting step
- No VFA accumulation

Ammonia toxicity

- In ADM1, ammonia inhibits only the methanogens
- Interaction between inorganic nitrogen, VFA and pH, which tends to stabilize the process.
- Since hydrolysis is the limiting step, a slight inhibition of methanogenesis does not affect the process

Conclusions and perspectives

- The modified ADM1 represents adequately the anaerobic digestion of *Chlorella vulgaris*
- The optimal productivity is obtained for a HRT of 20 d.
- The hydrolysis is the limiting step
- Ammonia does not destabilize the process

- Validation with experimental data (other species)
- Effect of pretreatment (thermal or ultrasonic treatments, or even lipid extraction)
- Simulation and optimization of the coupling between a microalgal pond and an anaerobic digester

Thank you for your attention !

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