STABILIZING FOOD WASTE ANAEROBIC DIGESTION

G. Capson-Tojo, M. Rouez, M. Crest,
J.-P. Steyer, N. Bernet, J.-P. Delgenès, **R. Escudié**

Lab. for Environmental Biotechnology
Narbonne – France

CIRSEE
Paris – France

What is Food Waste?

- **“Mass of food lost or wasted in the part of food supply chains leading to edible products for human consumption”**
- **1/3 of the food produced worldwide**
- **Main contributor of OFMSW**

FAO (2012), Gustavsson et al. (2011), Melikoglu et al. (2013), UN (2011)

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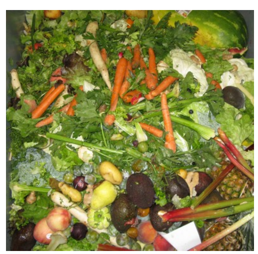

**Landfillin
g**

**Incineratio
n**

**Compostin
g**

**Anaerobic
digestion
(AD)**

FAO (2012), Gustavsson et al. (2011), Melikoglu et al. (2013), UN (2011)

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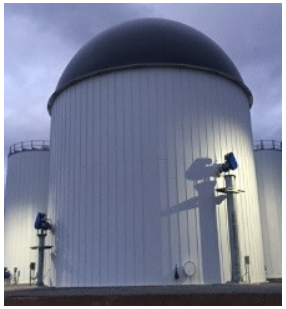
EU directive (2008/98/CE)
Valorization through soil return mandatory

Compostin
g



Anaerobic digestion (AD)

FW characteristics and AD

Common FW characteristics

Country	TS (% w/w)	VS (% TS)	Carbohydrates (%)	Proteins (%)	Lipids (%)	C/N
	23.7	91.4	41.4	15.1	23.5	13.9
	27.5	86.6	~56.4	16.1	17.5	18.3
	21.0	90.3	61.8	19.8	12.1	16.1

- **Several studies with FW as substrate for methane and/or hydrogen production**
- **Biochemical methane potentials (BMPs): 300-600 ml $CH_4 \cdot g\ VS^{-1}$**

Banks et al. (2012), Capson-Tojo et al. (2017a), VALORGAS (2010)

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SUITABLE SUBSTRATE

HOWEVER ...

- Several studies with FW as substrate for methane and/or hydrogen production
- Biochemical methane potentials (BMPs): **300-600 ml $CH_4 \cdot g\ VS^{-1}$**

Challenges in FW AD

Fast degradation

Main challenge in batch reactors: initial accumulation of VFAs and acidification

Organic matter

↓

VFAs

High protein content

Main challenge in long-term operation: accumulation of NH_3 and inhibition

Organic nitrogen

↓

NH_3

Inhibition methanogenic archaea

VFA accumulation

pH drop

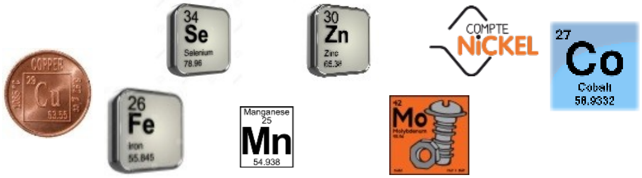
Stabilizing FW AD

Mono-digestion

- Unstable operation ("inhibited steady state")
- Failure even at low OLRs

- Addition of water as industrial solution: environmental and economical constraints

- Supplementation of trace elements (TEs)



Banks et al. (2012), Capson-Tojo et al. (2016), Nagao et al. (2012), Qiang et al. (2012)

TEs and FW

- **Required for the synthesis of enzymes**

- **Improved methane production rates and VFA degradation kinetics**
- **Higher OLRs achieved**

TEs in Commercial FW used

Compound	Concentration ($mg \cdot kg\ TS^{-1}$)
Fe	1,114
Co	non-detected
Cu	11.2
Mn	27.6
Mo	1.26
Zn	38.4
Ni	1.19
Se	?

Lack of TEs?

Banks et al. (2008, 2011), Capson-Tojo et al. (2017b), Yirong (2016), Zhang et al. (2017)

Objectives: comparison stabilization options

- **Avoid initial VFA peak: compare 3 strategies for stabilizing FW AD**

Working at low temperatures (30 °C)

$NH_3 + H^+ \leftrightarrow NH_4^+$

VS.

Co-digestion with paper waste (PW)

C/N, inhibitors dilution, buffering capacity, slower biodegradation

VS.

Addition of trace elements (TEs)

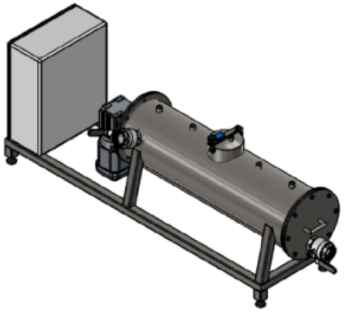
Enzyme synthesis

- **Consecutive batch reactor at increasing substrate loads**

process applicable at industrial scale

simulation a plug-flow reactor with digestate recirculation

Material and Methods



Research strategy

- **Four mixed pilot reactors**
- **Working volumes 7.5-20 l**
- **Mesophilic operation (37 °C)**
- **Commercial FW from GN**

fast food restaurant

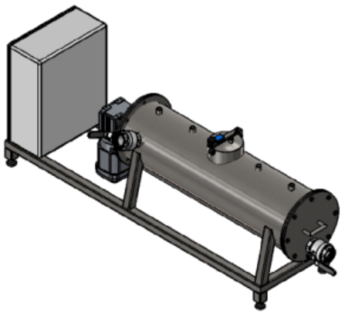
restaurant

supermarket

fruit & vegatable supermarket

fruit & vegatable distributor

Material and Methods



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- **Four mixed pilot reactors**
- **Working volumes 7.5-20 l**
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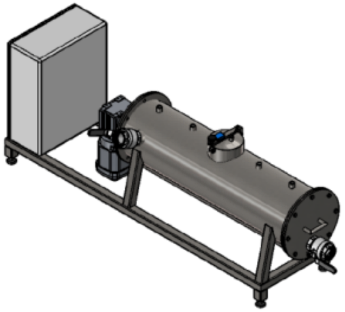
Specific conditions

- **Control: fed with FW**
- **T30: temperature of 30 °C**
- **Co-PW: fed with FW and PW (3:1 w/w)**
- **Sup-TEs: doped with TEs**

Compound	Concentration reactor ($mg \cdot l^{-1}$)
Fe	100
Co	1.0
Cu	0.1
Mn	1.0
Mo	5.0
Zn	0.2
Ni	5.0
Se	0.2

Material and Methods



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Feeding strategy

- **1st load: 0.087 kg FW·$kg_{inoculum}^{-1}$ (S/X 0.25 g VS·g VS^{-1})**
- **2nd load: 0.173 kg FW·$kg_{inoculum}^{-1}$**
- **3rd load: 0.260 kg FW·$kg_{inoculum}^{-1}$**
- **Twice each load**
- **Reactors fed if biogas plateau or 500 ml CH_4·g VS^{-1} reached**

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Control

Contro
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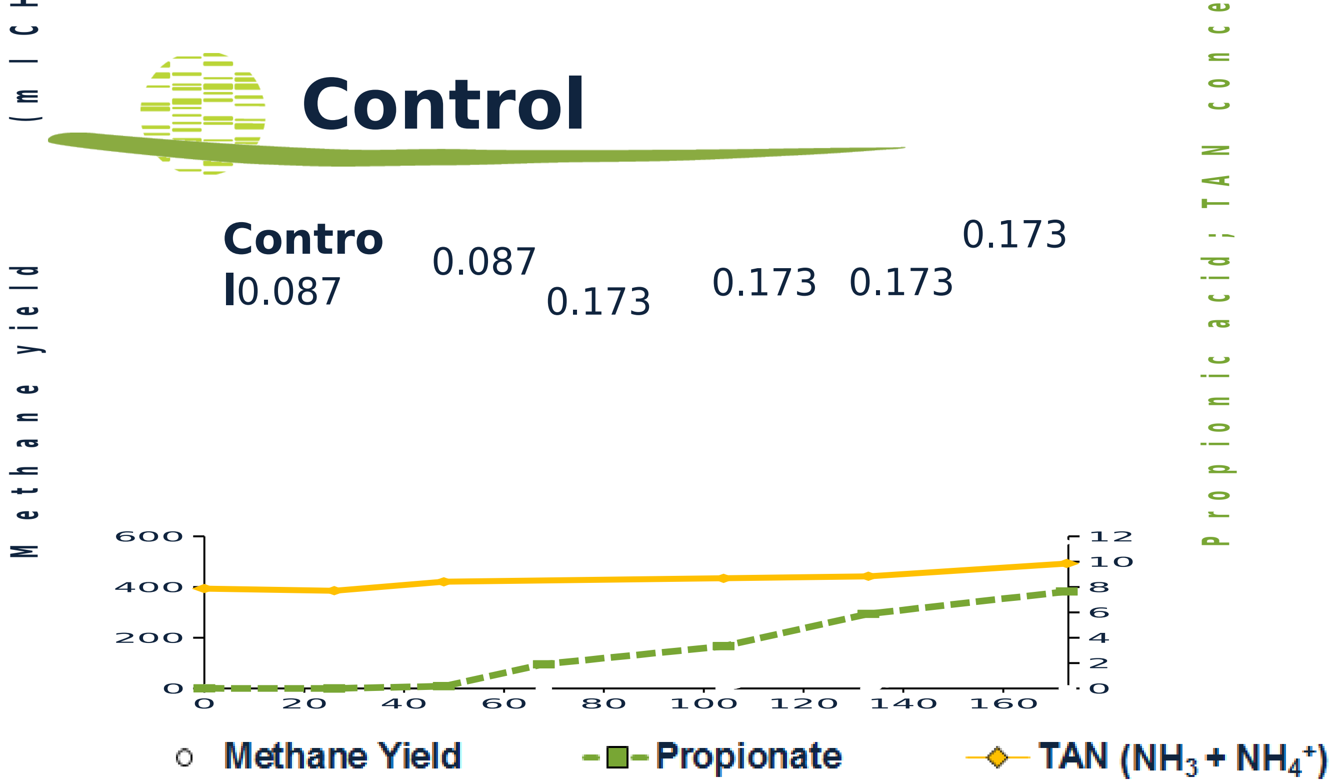
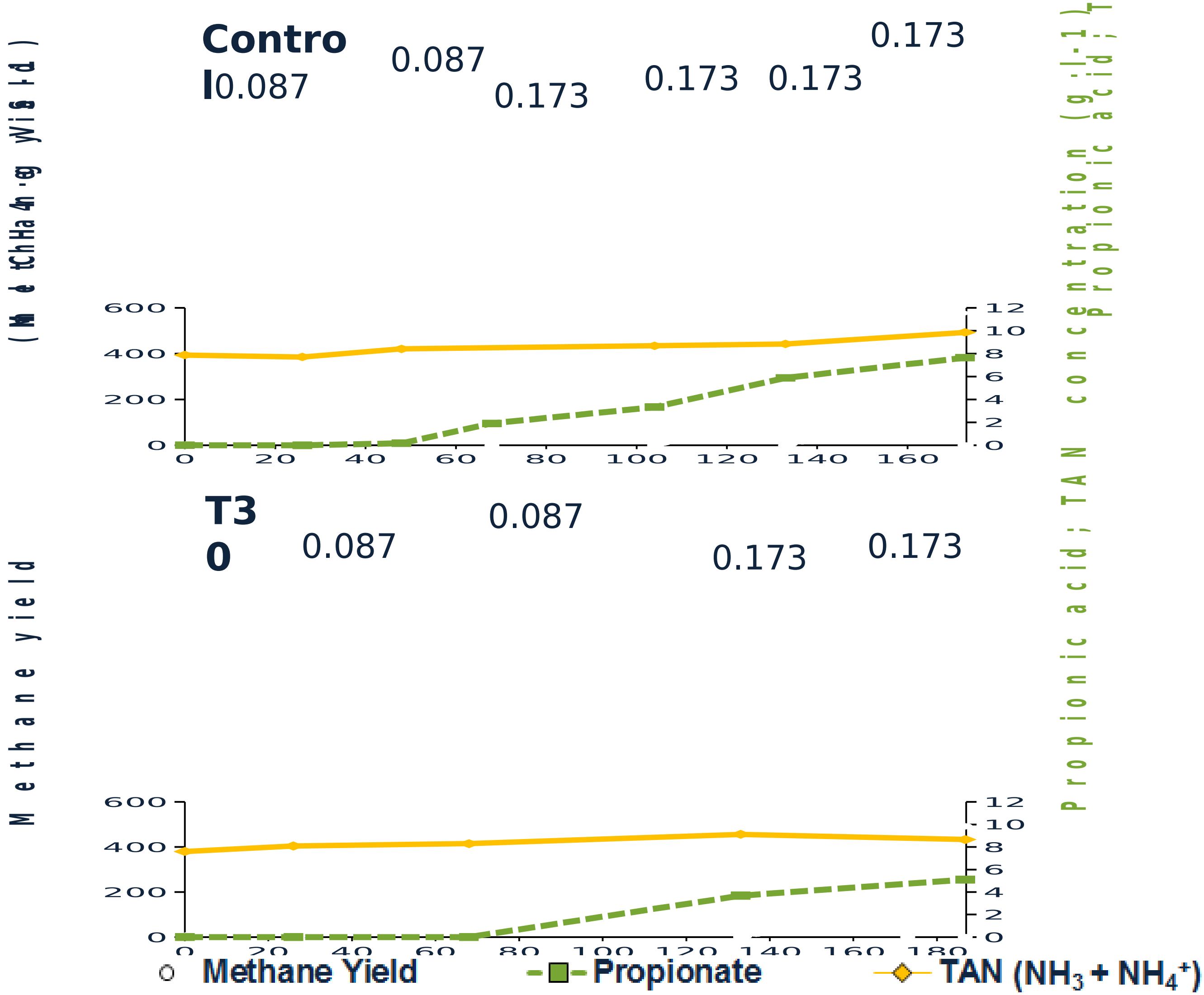


- **Continuous accumulation of propionic acid**
- **Gradual decrease of methane production rate & longer lag phase**

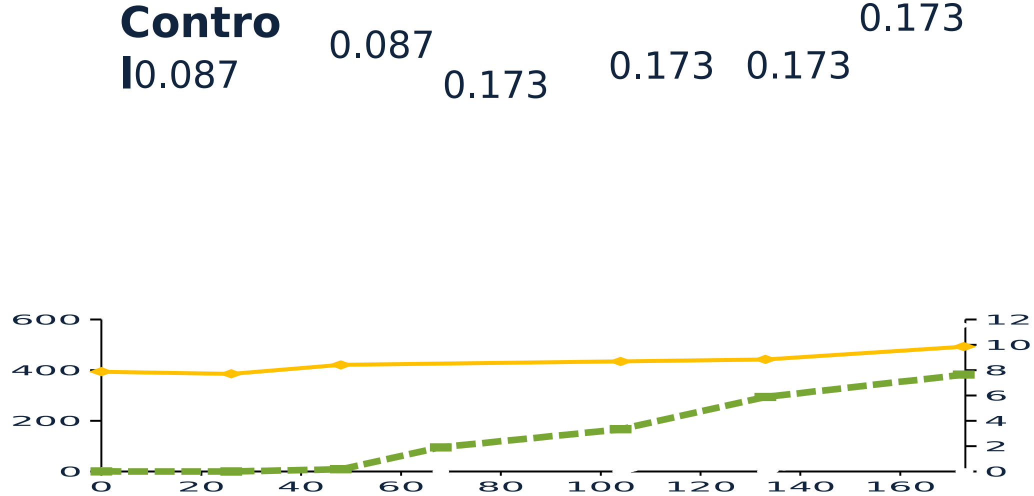
Control *VS.* T30



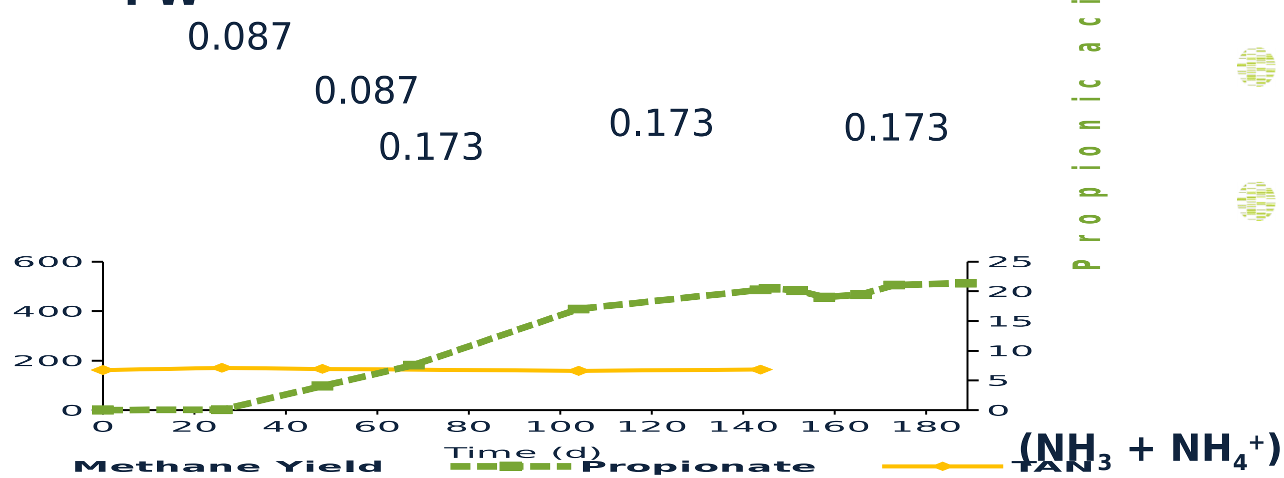
- **Continuous accumulation of propionic acid**
- **Gradual decrease of methane production rate & longer lag phase**
- **T30: slower kinetics and longer lag phase**
- **built-up of propionic acid**

Control *VS.* Co-PW

Control



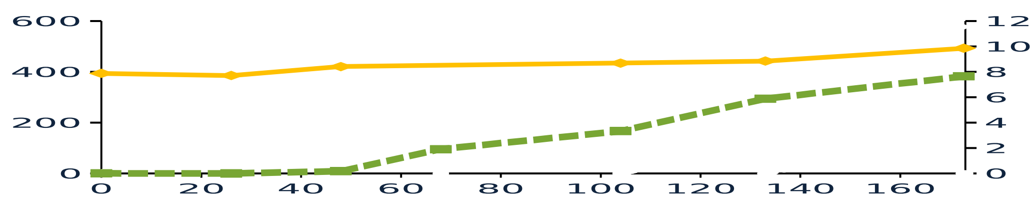
Co-PW



- **Continuous accumulation of propionic acid**
- **Gradual decrease of methane production rate & longer lag phase**
- **Co-PW: lower yields**
- **Higher accumulation of propionic acid (over 20 g·l^{-1})**

Control *VS.* Sup-TEs

Control 0.087 0.087 0.173 0.173 0.173 0.173



Sup-TEs 0.173 0.173 0.260 0.260

- **Continuous accumulation of propionic acid**
- **Gradual decrease of methane production rate & longer lag phase**
- **Sup-TEs: faster kinetics but still propionic acid**
- **Inhibition at 0.260 kg $FW \cdot kg_{inoculum}^{-1}$**

Conclusions

- **Propionic acid accumulation => key issue for FW AD**
- **Acidification at high loads**
- **Low temperature and co-digestion with PW: discarded**
- **TEs addition: improved kinetics and higher substrate loads (but still propionic acid accumulation)**

Operational implications

- **Batch mode might not be the best option**
- **Methane production cannot be used as sole criteria for reactor feeding**

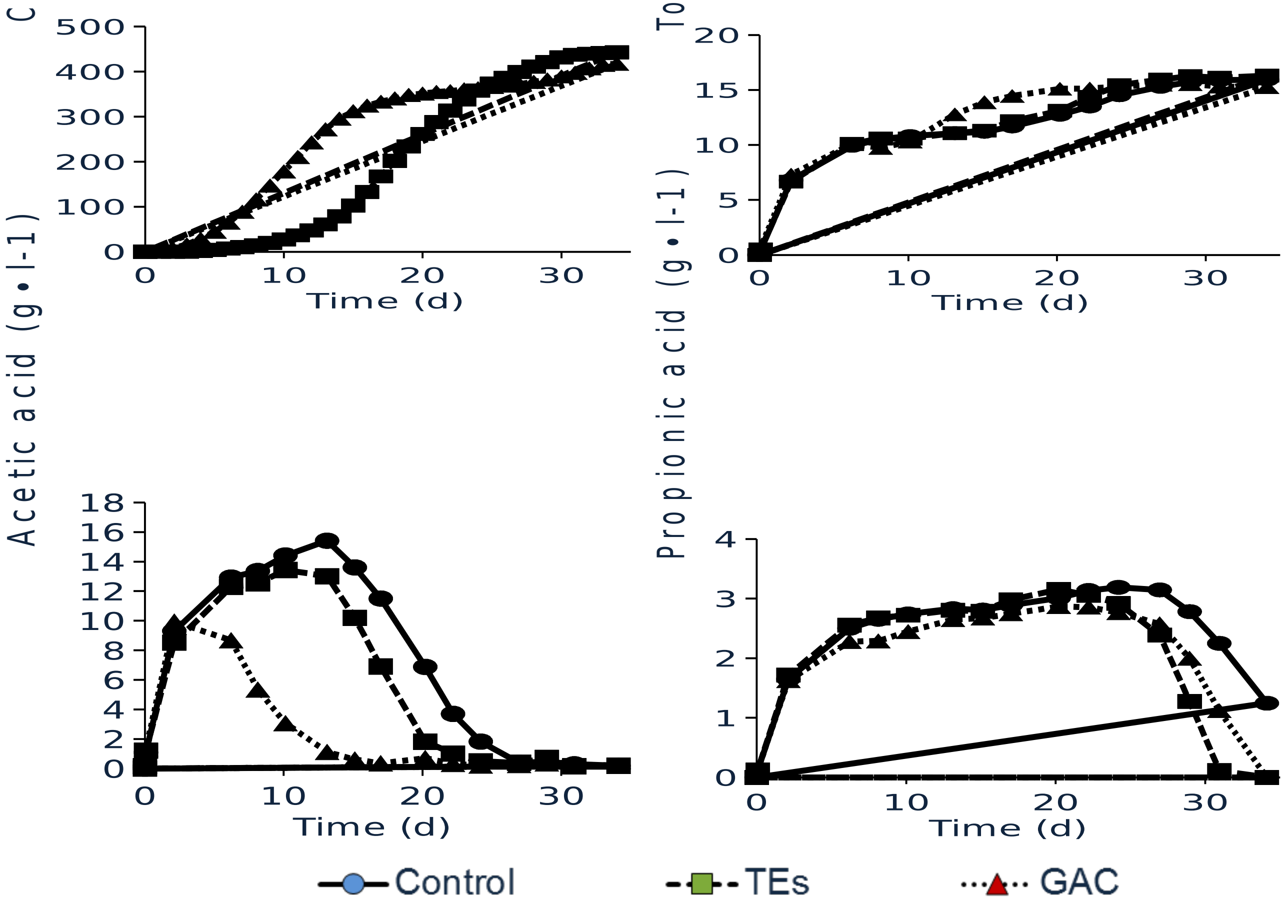
Research challenges

- **Favor consumption of: propionic acid and/or HAc and/or H_2**

Thank you for your kind attention

LBE, INRA (France) http://www1.montpellier.inra.fr/narbonne/
renaud.escudie@inra.fr

1st batch: GAC and TEs



- **Similar methane yields and COD conversions**
- **Lag phases in methane production**

+ GAC

- **Shorter lags**
- **Stability up!**
- **Improvement due to favored HAc consumption**
- **Propionic acid consumption not improved…**

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