ATHENS2017

5th International Conference on Sustainable Solid Waste Management

Acidogenic fermentation and anaerobic codigestion of non-source sorted OFMSW and Polyethylene glycol

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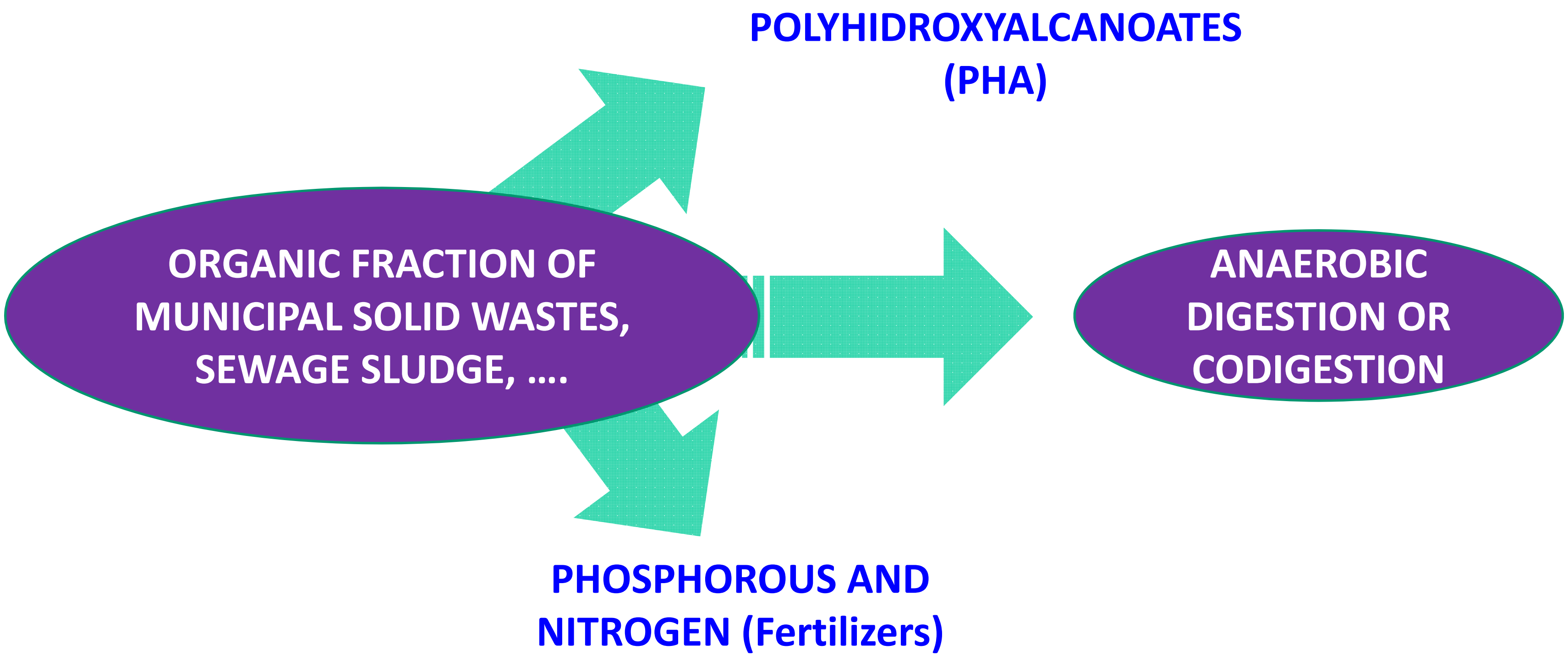
- Nowadays, new strategies for organic wastes of urban/industrial origin are focused to reach more CIRCULARITY. In this framework:

  - The value of the products, **materials** and **resources** should be maintained in the economy the longer time possible (**reuse, recycling**).

  - Waste generation should be **minimized**



ANAEROBIC DIGESTION AND CODIGESTION OF RESIDUAL ORGANIC MATTER (ROM) (non-source sorted OFMSW)

Non-source sorted OFMSW (ROM)

Mechanical-biological treatment plants

If PHA is produced, biogas production in AD should be increased

Polyethylene glycol (PEG) has many **applications**, from **industrial** manufacturing to **medicine** production, and can be found in some industrial wastewaters.

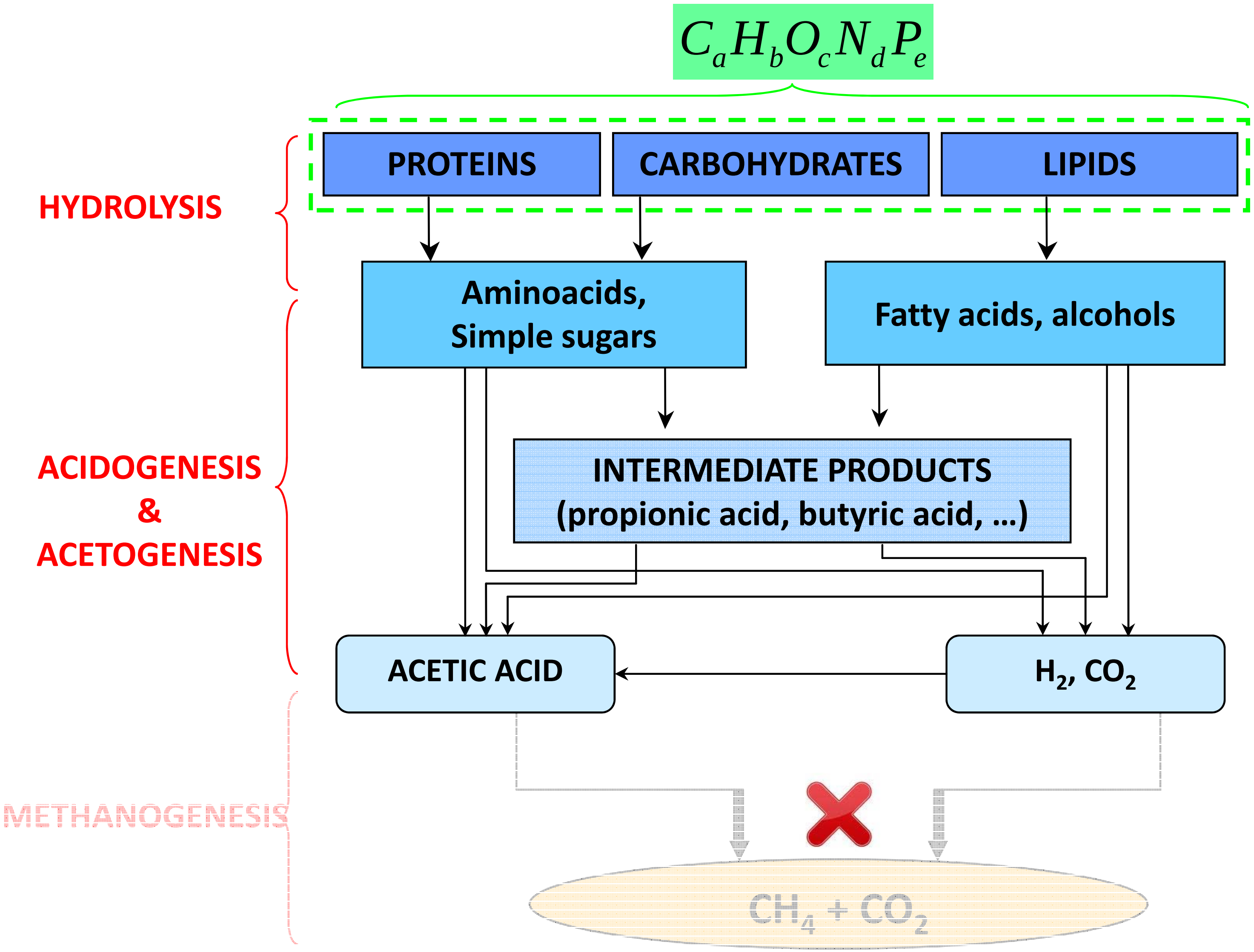
LIMITATIONS IN ANAEROBIC DIGESTION OF PURE PEG

COULD BE OVERCOMED BY

ROM + PEG CODIGESTION

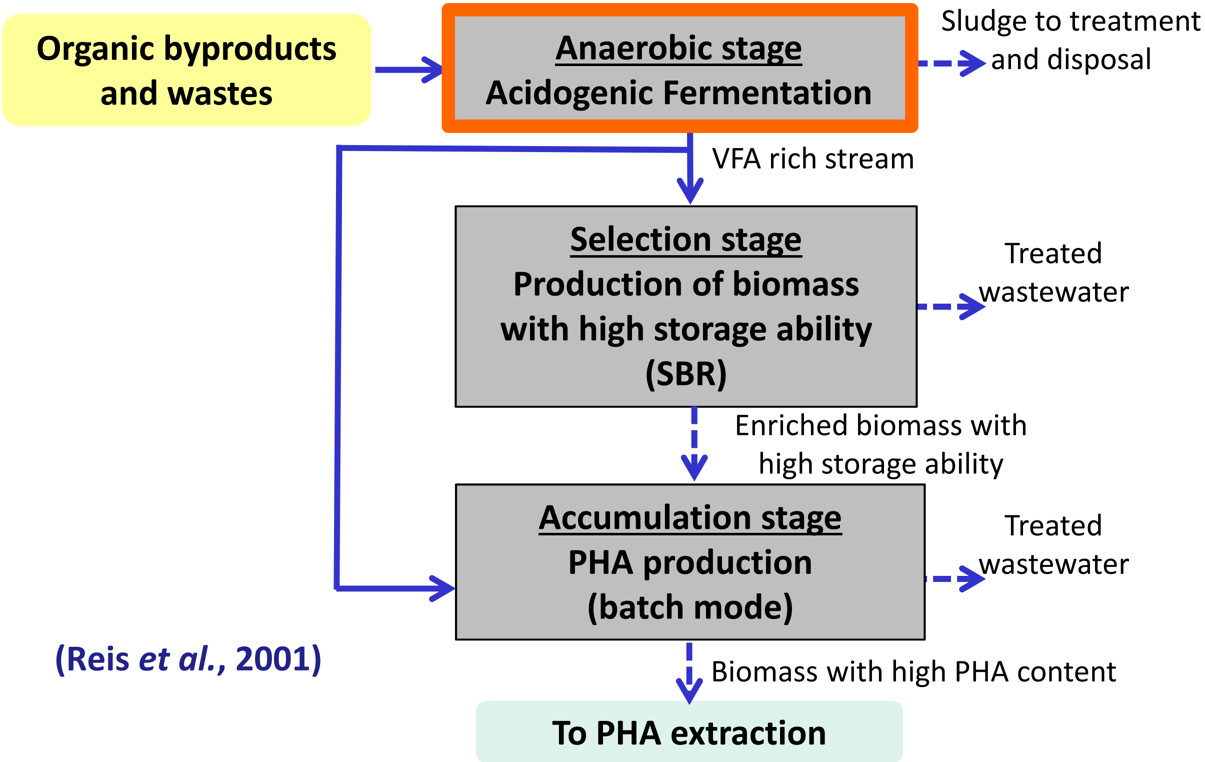
Synergistic Effect

ACIDOGENIC FERMENTATION



PHA PRODUCTION FROM URBAN ORGANIC WASTES

- **PHA** is a high value added product and its price could be reduced by using **Mixed Microbial Cultures** (MCC) and **fermentable organic wastes**.



(Reis *et al.*, 2001)

ACIDOGENIC FERMENTATION

- The use of **Mixed Microbial Cultures** could ferment heterogeneous organic wastes like the **OFMSW**

Operational parameters of the fermenter:

- **HRT**
- **SRT**
- **pH**
- **TEMPERATURE**
- **ORGANIC LOAD**

TUNING OF

- ✓ **VFA concentration**
- ✓ **VFA composition**
- ✓ **$COD_{VFA}/COD_{SOLUBLE}$ Ratio**
- ✓ **NH_4^+-N concentration, ….**

PRETREATMENTS

- Chemical (acid, alkaline, O_3, H_2O_2, …)
- Biological (enzymes dosing, bioaumentation, …)
- Physical treatments (thermal, ultrasound, …)
- Pretreatments combination
- Others

CO-FERMENTATION WITH OTHER ORGANIC WASTES

PHA ACUMULATION WITH FERMENTATION LIQUIDS OF OFMSW

SUBSTRATE	PERCENTAGE OF PHA (g PHA g^{-1} VSS)	MASSIC COD/N/P RATIO	Reference
ACETATE	0.69-0.89	100/0/0.1-1.2	Johnson *et al.* (2009)
ACETATE	0.79	100/5/1.5	Valentino *et al.* (2015)
SINTHETIC VFA MIXTURE	0.52	-	Duque *et al.* (2014)
FERMENTED SEWAGE SLUDGE	0.57	100/3/0.4	Mengmeng *et al.* (2009)
LIQUID FRACTION OF FERMENTED SEWAGE SLUDGE	0.21*	100/7.8/0.06	Frison *et al.* (2015)
OFMSW LEACHATES	0.29	10.4/1.2/0.002	Korkakaki *et al.* (2016)
LIQUID FACTION OF FERMENTED OFMSW	0.11*	100/4.5/0.42	Basset *et al.* (2015)
LIQUID FACTION OF FERMENTED non source sorted OFMSW	0.18	100/11.4/-	Martín-Ryals *et al.* (2016)

* The process included Biological Nitrogen removal over nitrite

ANAEROBIC CODIGESTION AND COFERMENTATION OF ROM+PEG rich WW

- EXCESS OF NUTRIENTS
in the fermentation liquid

1,5-3,0 g N-NH_4^+ L^{-1}

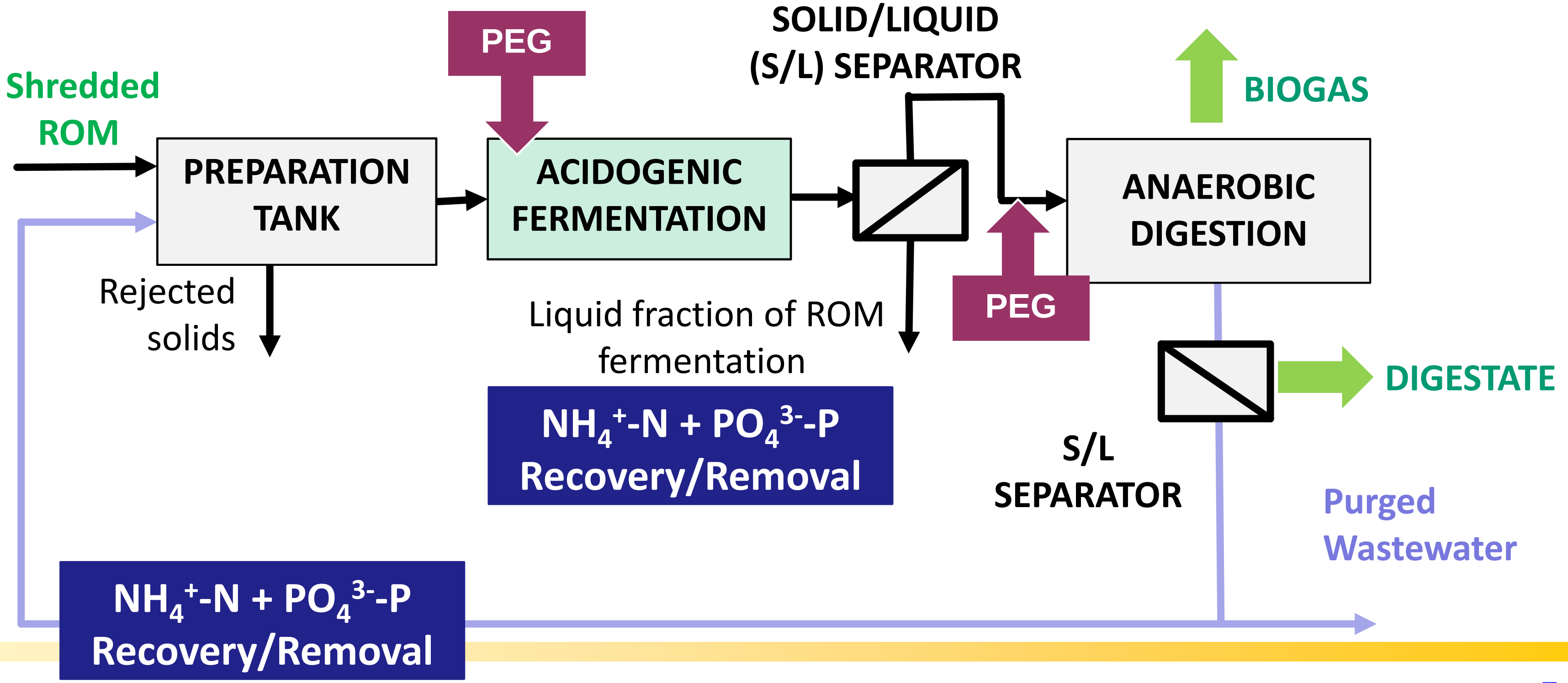
< 0,5 g P-PO_4^{3-} L^{-1}

Martin-Ryals et al. (2016)

- Unfavourable $COD_{VFA}/COD_{SOLUBLE}$

→ **REDUCTION** in **PHA** accumulation

(bacterial growth is promoted instead of PHA accumulation)



OBJETIVES

To study the effect of using PEG-industrial wastewater for:

- **Anaerobic codigestion with ROM**
- **Acidogenic co-fermentation with ROM**

EXPERIMENTAL DEVICES

Lab-scale anaerobic digester and codigester (5L)

Batch test assays for acidogenic fermentation

Acidogenic fermentation lab-scale reactor (5L)

ANALYTICAL METHODS

Standard Methods for the Examination of Water and Wastewater (APHA, 2012)

SUBSTRATE AND INOCULUM

REACTORS	SUBSTRATES	INOCULUM
Anaerobic Codigesters Acidogenic Fermentation	RESIDUAL ORGANIC MATTER (ROM) + Supernatant from Anaerobic Digestion of ROM [Mechanical biological treatment plant Metropolitan Area of Barcelona] PEG RICH INDUSTRIAL WASTEWATER [Pharmaceutical Industry]	Anaerobic digestion biomass from a mesophilic digester treating ROM

ROM AND PEG CHARACTERISTICS

ROM CHARACTERIZATION		
Parameter	Units	Value
pH	-	6.5-7.0
Total Solids (TS)	% w/w	5.0 ± 1.1
Volatile Solids (VS)	% w/w	3.9 ± 0.9
Total Alkalinity	mg $CaCO_3$ L^{-1}	3,230.5 ± 489.0
Total VFA	mg L^{-1}	1,176 ± 348
NH_4^+-N	mg L^{-1}	> 1,067

PEG-RICH INDUSTRIAL WASTEWATER CHARACTERIZATION		
Parameter	Units	Value
pH	-	4.5-5.0
Total Solids (TS)	% w/w	45.04 ± 1.02
Volatile Solids (VS)	% w/w	44.61 ± 1.03
Total Alkalinity	mg $CaCO_3$ L^{-1}	1,867.5 ± 42.5
Total VFA	mg L^{-1}	657.4 ± 1.5
NH_4^+-N	mg L^{-1}	5.15 ± 0.5
NO_x^--N	mg L^{-1}	n.d.
Sulfites and sulfates (SO_X^{2-}-S)	mg L^{-1}	n.d.

n.d.: not detected

ANAEROBIC CODIGESTION OF ROM AND PEG

<u>*Operating conditions:*</u>

- HRT 20 days
- Temperature 35^{o}C
- Feeding manually once a day
- ROM collected 3 times/week

Two Stages

1) ANAEROBIC DIGESTION (2 reactors)
(simulating the industrial operation)

2) ANAEROBIC CO-DIGESTION ROM+PEG
implemmented in one digester

ANAEROBIC CODIGESTION OF ROM AND PEG

STAGE 1) ANAEROBIC DIGESTION (2 reactors)

	REACTOR A	REACTOR B
HRT (days)	20	20
Specific Methane Production, SMP (m^3 CH_4 (kg VS)$^{-1}$)	0.31 ± 0.02	0.29 ± 0.02
Methane content (% v/v)	61.42 ±0.72	59.88± 0.74
TS removal (%)	60.27 ± 3.37	63.88 ± 1.03
VS removal (%)	73.84 ± 1.48	77.45 ± 1.83
TS content in effluent (%)	1.73 ± 0.09	1.58 ± 0.06
VS content in effluent (%)	0.84 ± 0.04	0.74 ± 0.03
Average VFA (mg L^{-1})	193±74	227±114
Alkalinity (mg $CaCO_3$ L^{-1})	6908 ±919	6386 ± 408
pH	7.65 ± 0.13	7.72 ± 0.13
Effluent pH	6.6 ± 0.2	6.5 ± 0.2

Implemmentation of AcoD

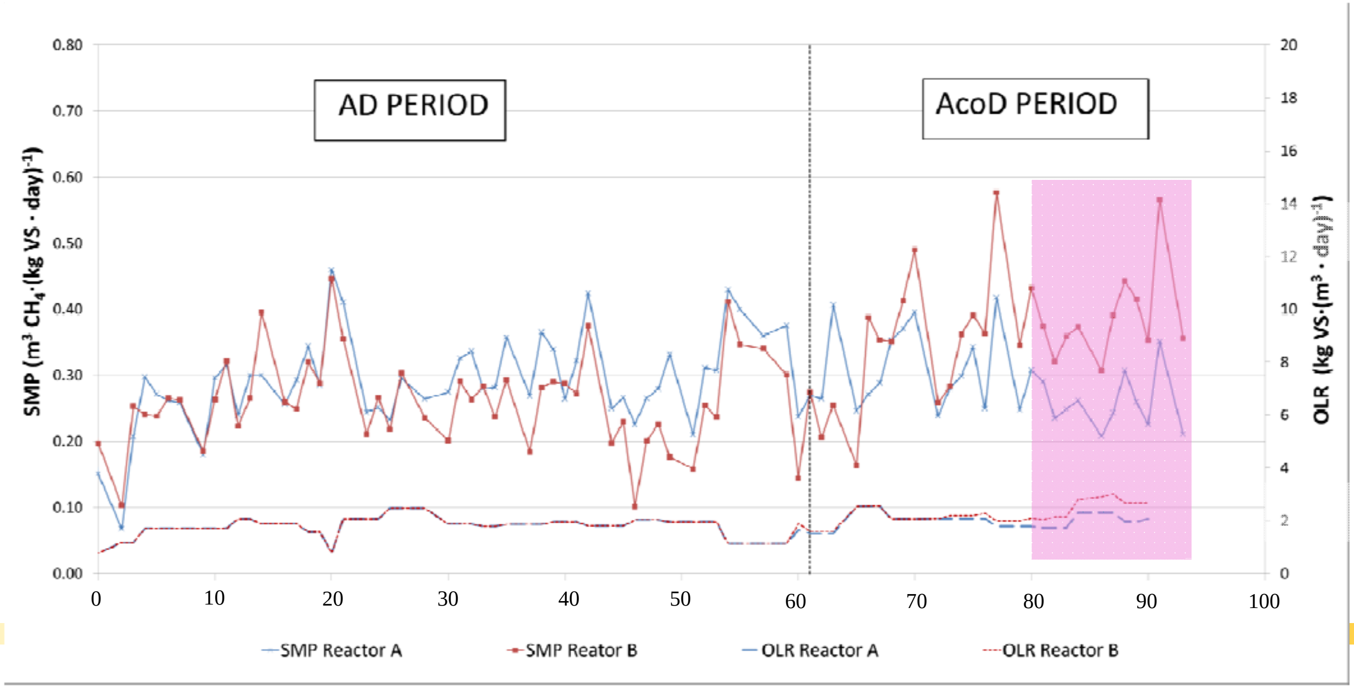
ANAEROBIC CODIGESTION OF ROM AND PEG

STAGE 2) ANAEROBIC DIGESTION AND CODIGESTION

REACTOR B → **PEG + ROM Codigestion (up to 3.5% v/v PEG wastewater)**

REACTOR A — **OLR** 1.47 ± 0.43 kg VS (m^3 reactor day)$^{-1}$

REACTOR B — **OLR** 2.25 ± 0.43 kg VS (m^3 reactor day)$^{-1}$ **AVERAGE 34% VS PEG wastewater**

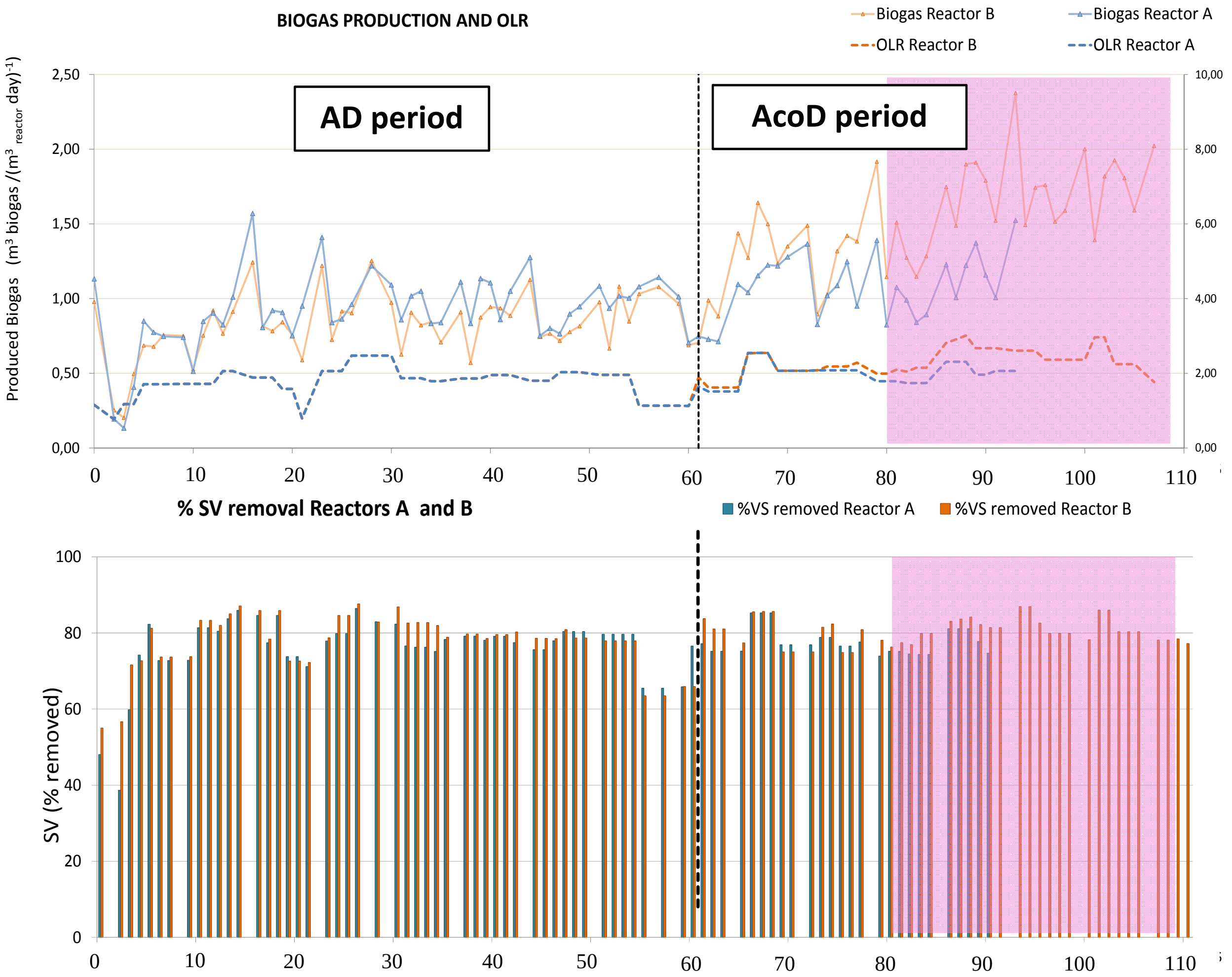


0.44 m^3 CH_4 (kg VS)$^{-1}$

0.30 m^3 CH_4 (kg VS)$^{-1}$

ANAEROBIC CODIGESTION OF ROM AND PEG

STAGE 2) ANAEROBIC DIGESTION AND CODIGESTION



PEG + ROM Codigestion (3.5% v/v PEG wastewater)

REACTOR B

Higher Biogas production

Higher VS removal

ANAEROBIC CODIGESTION OF ROM AND PEG

STAGE 2) ANAEROBIC DIGESTION AND CODIGESTION

	REACTOR A	REACTOR B
HRT (days)	20	20
OLR related to PEG wastewater (kg VS (m^3 reactor day)$^{-1}$)	-	0.78
Total OLR (kg VS (m^3 reactor day)$^{-1}$)	1.47 ± 0.43	2.25 ± 0.43
Specific Methane Production, SMP (m^3 CH_4 (kg VS)$^{-1}$)	0.30 ± 0.05	0.44 ± 0.08
Methane content (% v/v)	61.42 ±0.72*	61.82 ± 0.77
TS removal (%)	60.27 ± 3.37*	65.84±1.46
VS removal (%)	73.84 ± 1.48*	79.53 ±0.82
TS content in effluent (%)	1.92 ± 0.11	1.94 ± 0.15
VS content in effluent (% on TS)	48.44 ± 0.21	48.83 ±0.84
Average VFA (mg L^{-1})	193±74*	195 ± 30

34% VS PEG wastewater

* Previous stage – Reactor A

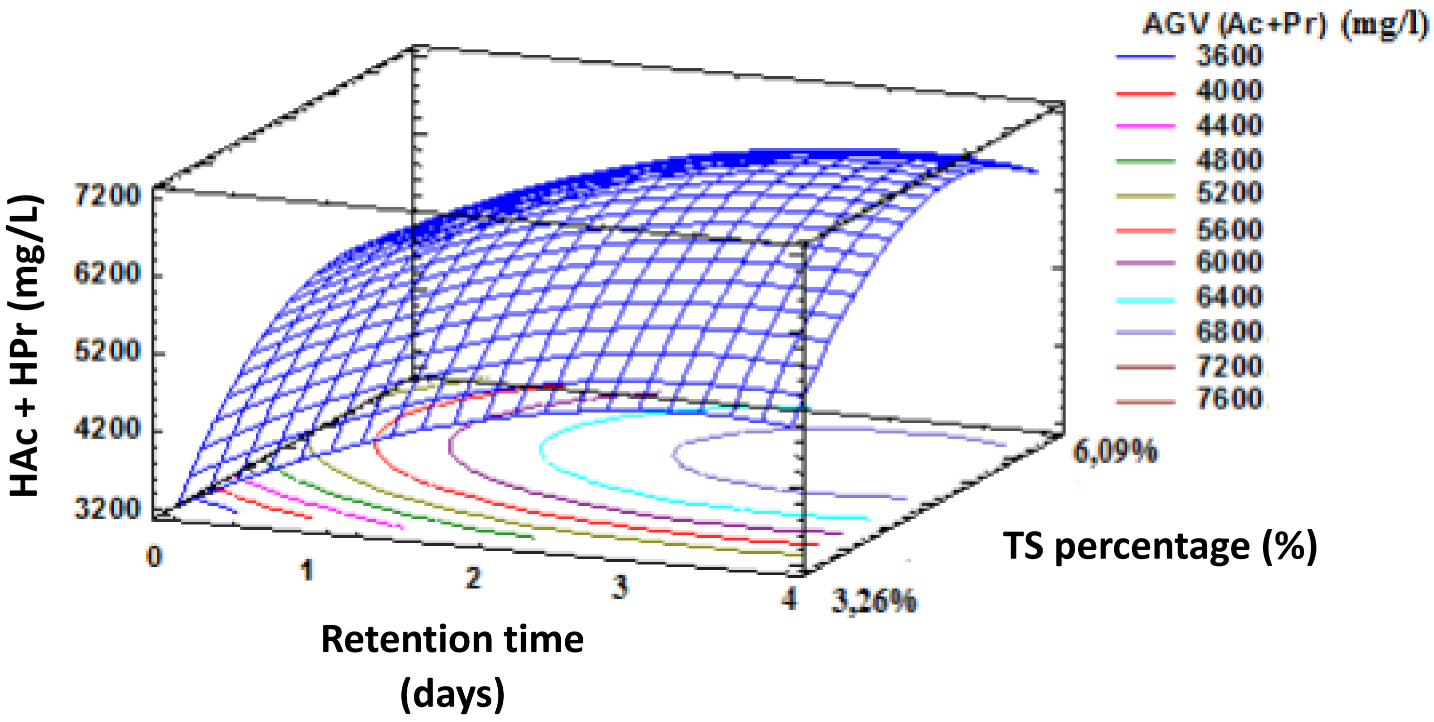
ACIDOGENIC FERMENTATION OF ROM - BATCH TESTS

Tested parameters in batch experiments:

- Retention time (0-5 days)
- % TS (3.3 - 8.2 %)
- Temperature (33 - 37ºC)

BEST VFA PRODUCTION RESULTS:

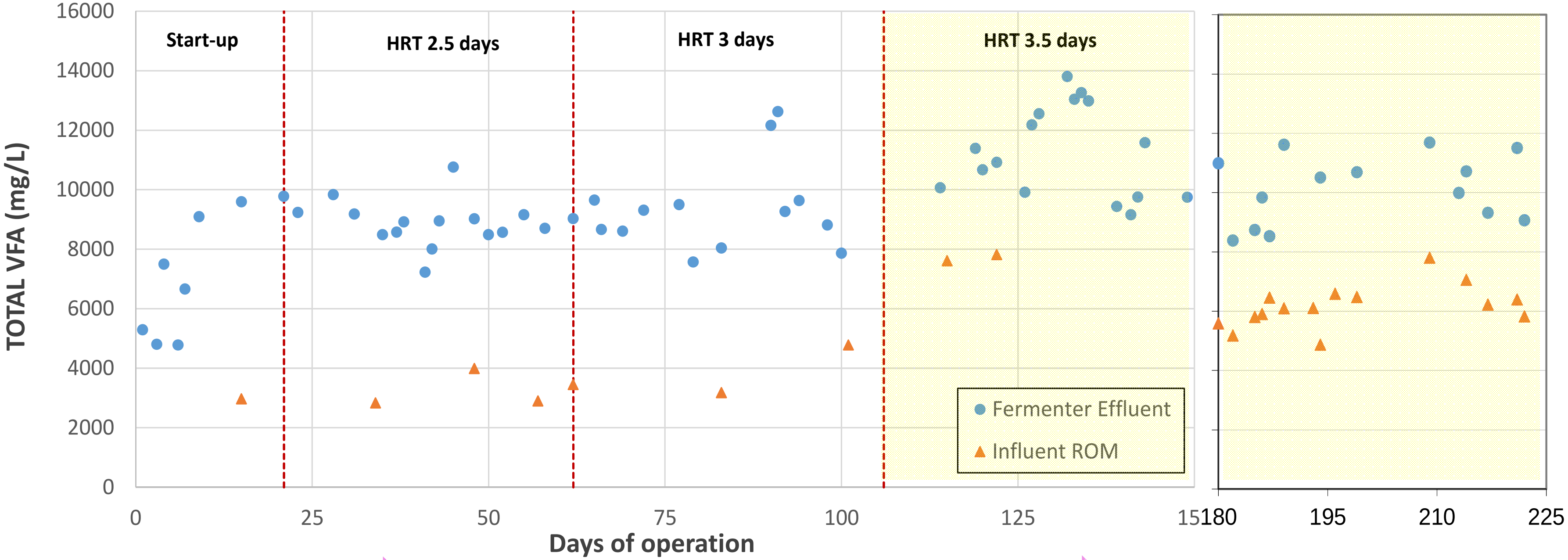
TS: 5.4 %; HRT: 3.4 days; T: 37 ºC



ACIDOGENIC FERMENTATION OF ROM

- Inoculum: AD biomass
- Initial HRT: 2.5 d to wash-out methanogens
- Temperature 37°C; No pH control

Continuous operation:

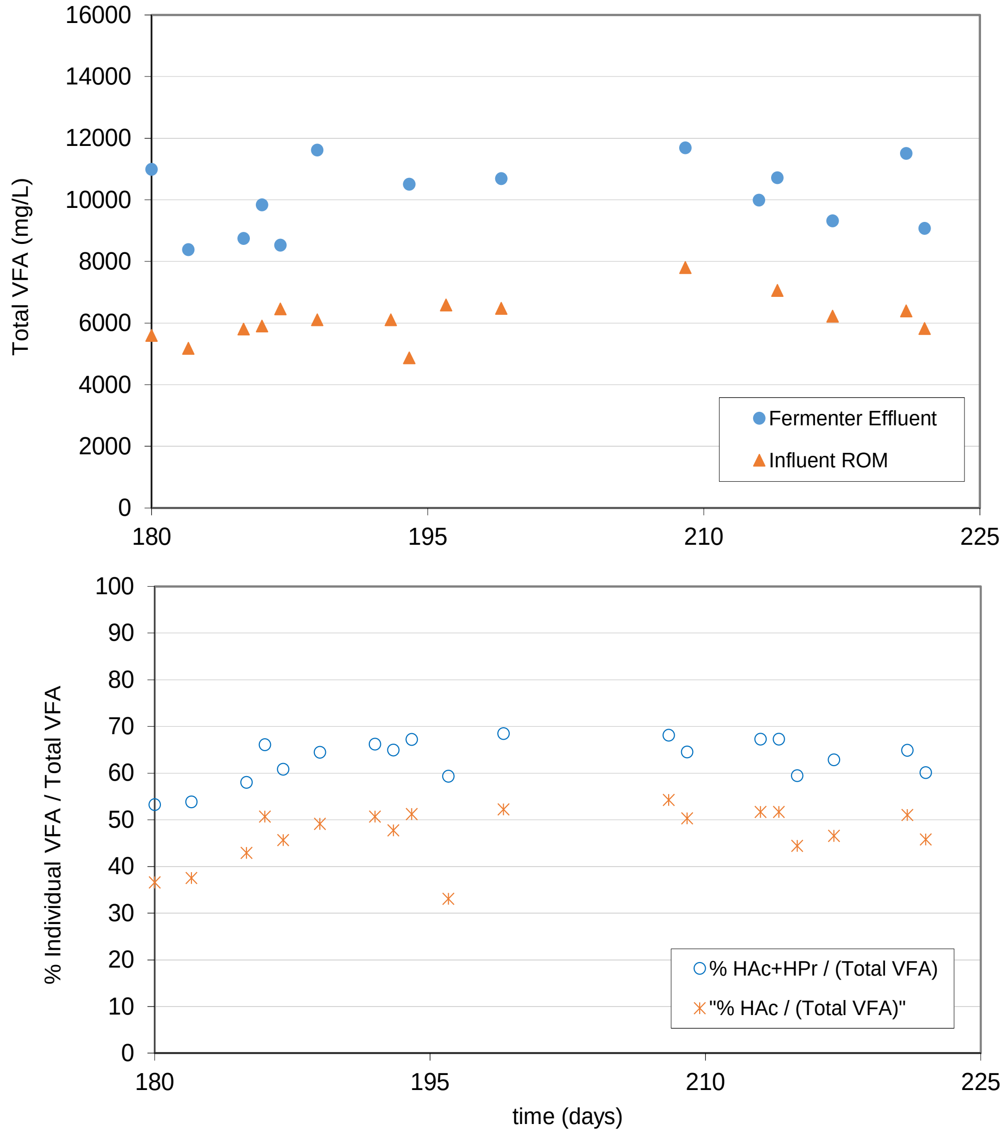


Higher HRT ⇒ **Higher VFA concentration** ⇒ **Higher % HAc+HPr**

HRT = 2.5 days	Average VFA concentration 8.8 ± 0.8 g L^{-1}	55.3 % HAc + HPr
HRT = 3.0 days	Average VFA concentration 9.4 ± 1.5 g L^{-1}	56.4 % HAc + HPr
HRT = 3.5 days	Average VFA concentration 10.7 ± 1.7 g L^{-1}	64.6 % HAc + HPr

ACIDOGENIC FERMENTATION OF ROM

	ROM Fermentation
HRT (days)	3.5
TS influent (%)	6.05 ± 0.86
VS influent (%)	4.07 ± 0.59
Average VFA (g L^{-1})	10.7 ± 1.7
% HAc + HPr (%)	64.6 ± 4.6
COD_{VFA}/COD_{SOL} (-)	> 0.57
Effluent pH	6.6 ± 0.2
Effluent NH_4^+-N (g L^{-1})	2.54 ± 0.58



ACIDOGENIC FERMENTATION OF ROM AND PEG – BATCH TESTS

Tested parameters:

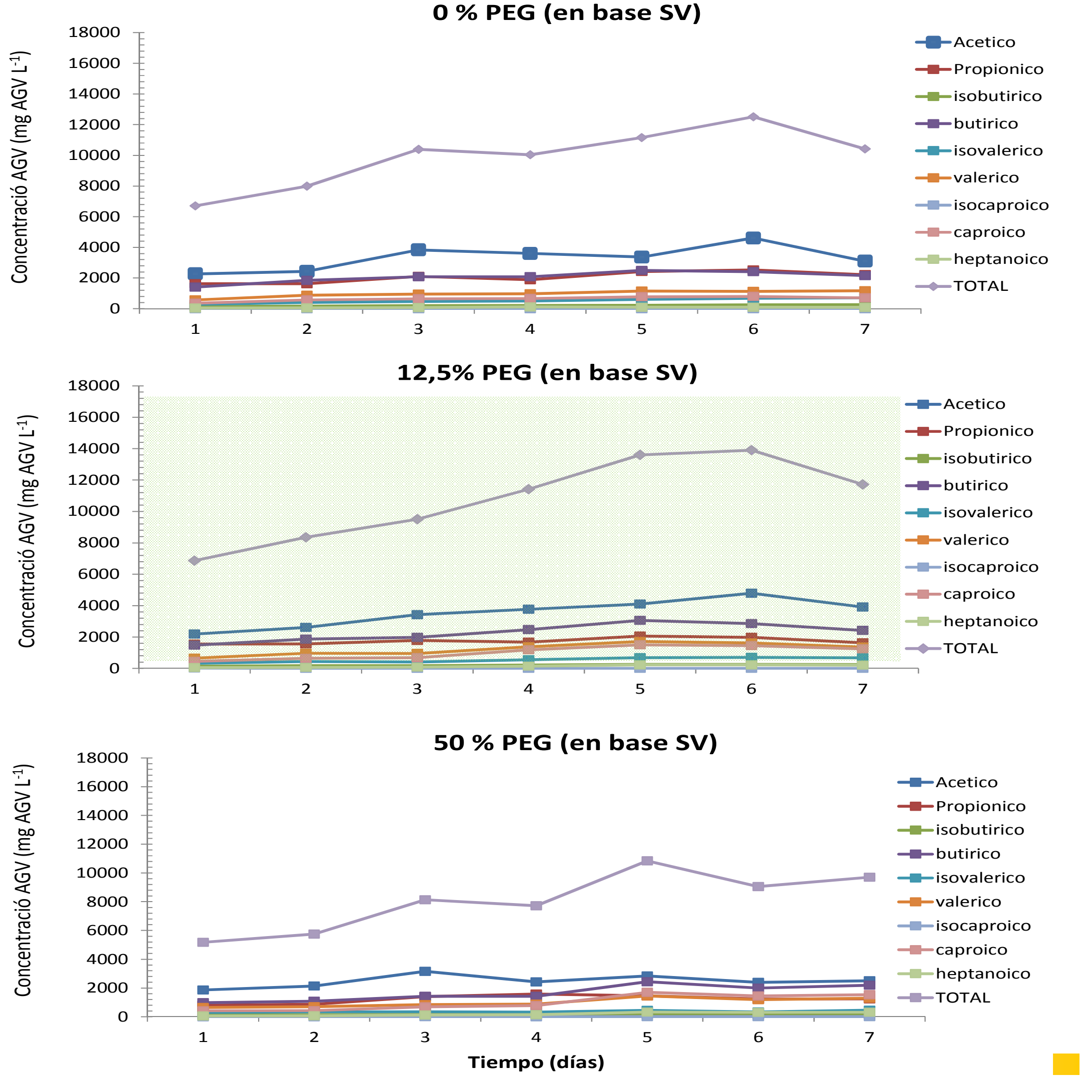
- Mixtures PEG – ROM (% PEG on VS basis):
0, 12.5, 25, 37.5, 50 %

- % TS (5.4%)

- Temperature (37ºC)

% PEG (% VS)	Average increase of VFA in the test with respect to 0 %PEG
12.5	X 1.22
25.0	X 1.25
37.5	X 1.32
50.0	X 0.97

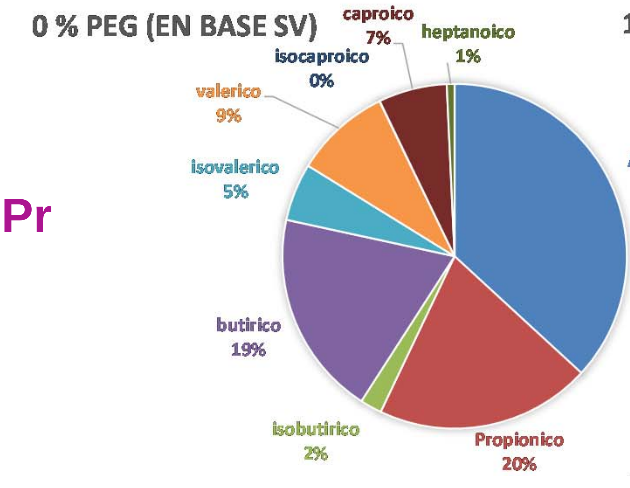
12.5% PEG -> 33.4% VFA increase

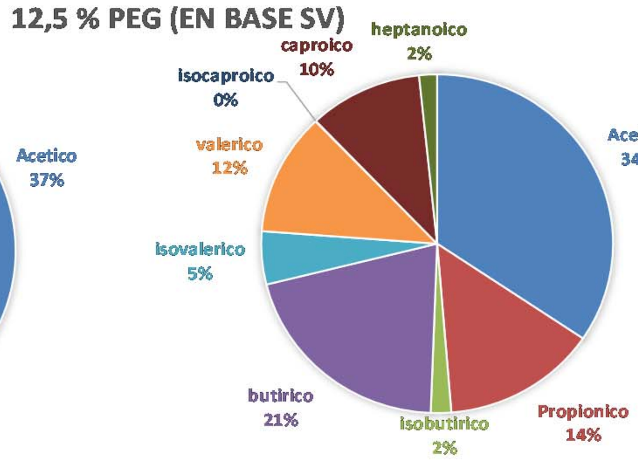


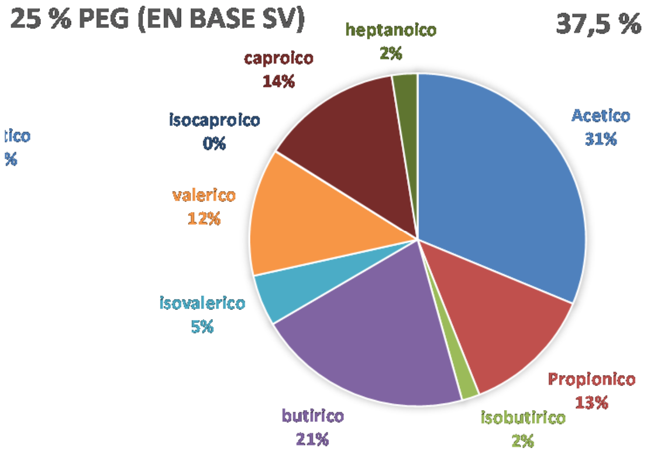
ACIDOGENIC FERMENTATION OF ROM AND PEG – BATCH TESTS

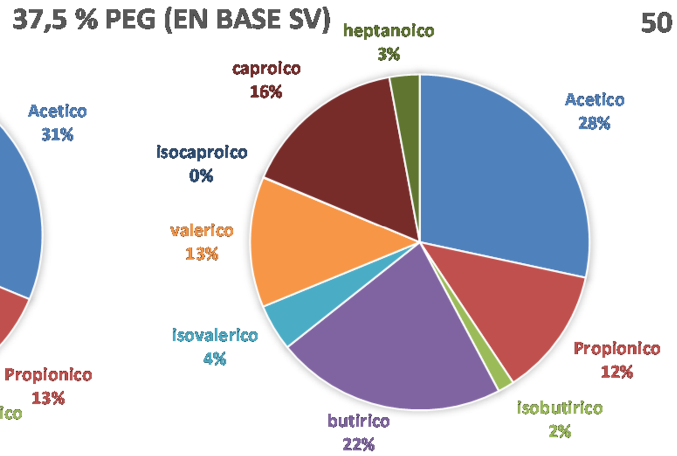
Higher % PEG

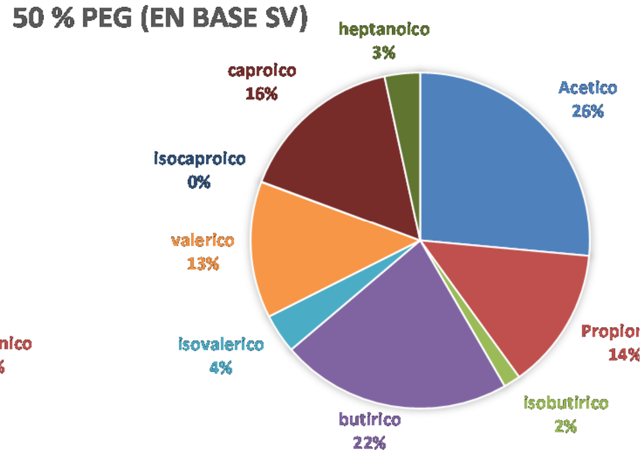
Lower % HAc + HPr with respect to total VFA





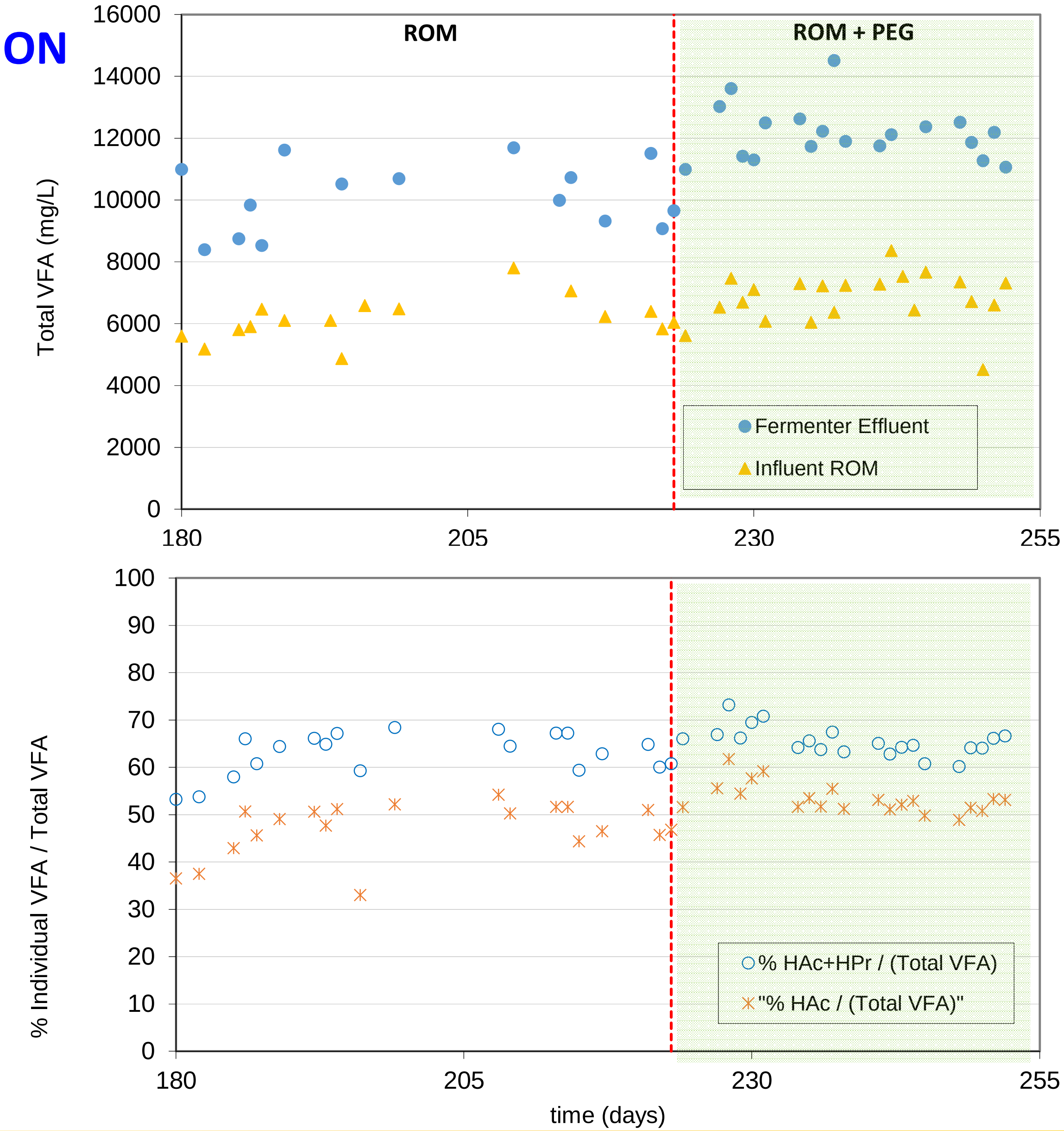




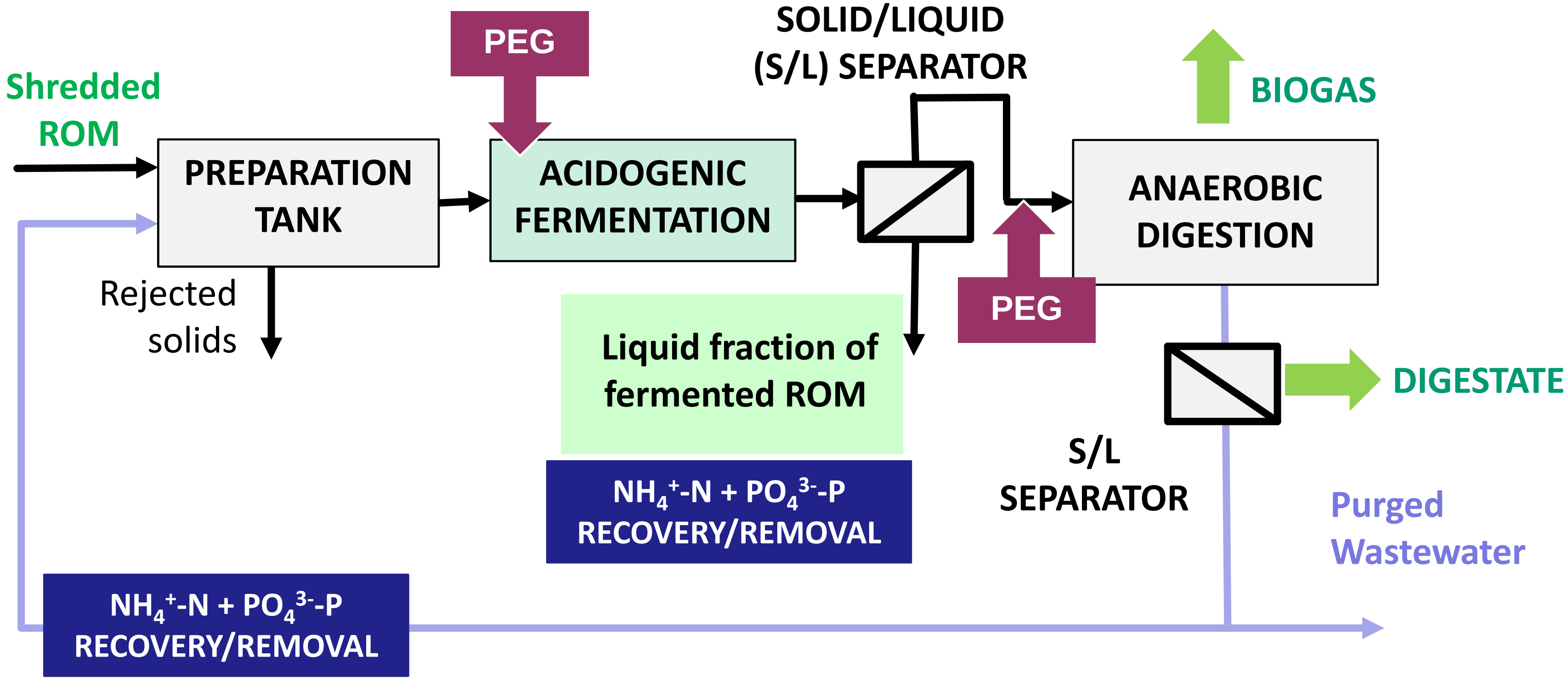


ROM + PEG CO-FERMENTATION

	ROM Ferment.	ROM + PEG Ferment.
HRT (days)	3.5	3.5
TS influent (%)	6.05 ± 0.86	6.17 ± 1.05
VS influent (%)	4.07 ± 0.59	4.13 ± 1.36
Average VFA ($g\ L^{-1}$)	10.7 ± 1.7	12.1 ± 1.3
% HAc + HPr (%)	64.6 ± 4.6	66.5 ± 3.5
COD_{VFA}/COD_{SOL} (-)	> 0.57	>0.62
Effluent pH	6.6 ± 0.2	6.5 ± 0.2
Effluent NH_4^+-N ($g\ L^{-1}$)	2.54 ± 0.58	2.46 ± 0.49



ROM + PEG CO-TREATMENT FOR THE PRODUCTION OF PHA



PEG-rich wastewater co-fermentation and co-digestion with ROM could be a feasible option to produce VFA for PHA production maintaining biogas production in the anaerobic digester of the existint plant.

However, further investigation is needed (digestate quality, nutrients recovery, ...). Besides, pilot plant tests should also be performed before scaling up to confirm these results and that no other problems appear (for example, due to changes in the wastewater recirculation composition).

CONCLUSIONS

- ✓ The use of PEG-rich industrial wastewater as co-substrate has been assessed as a feasible alternative to improve biogas production in the anaerobic digestion of ROM, without affecting the reactor stability and with no external nutrient supply. When the OLR was increased by 35% (on VS basis) due to co-substrate addition, an increase of the SMP by approximately 50% was registered.
- ✓ The introduction of PEG-rich industrial wastewater (co-substrate) for acidogenic fermentation of ROM lead to higher VFA production. At short term conditions the highest VFA increase per unit of VS of PEG wastewater added was recorded for a mixture of ROM and PEG with 12.5 % of co-substrate on VS basis and the proportion of VFA of C4, C5 and C6 was higher when compared with acidogenic fermentation of ROM.
- ✓ However, during long-term experiments of co-fermentation (12.5 % on VS basis of PG co-substrate) an acclimation of biomass was observed and higher percentages of acetic acid and propionic acid (66.5%) to total VFA were recorded, with an increase of VFA production of 14% with respect to mono-fermentation of ROM (maintaining the OLR on VS basis).

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