GREENPROPULSIONLAB

Co-fermentation of organic waste and sewage sludge after cavitation for VFAs production and subsequent biomethanization

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Background

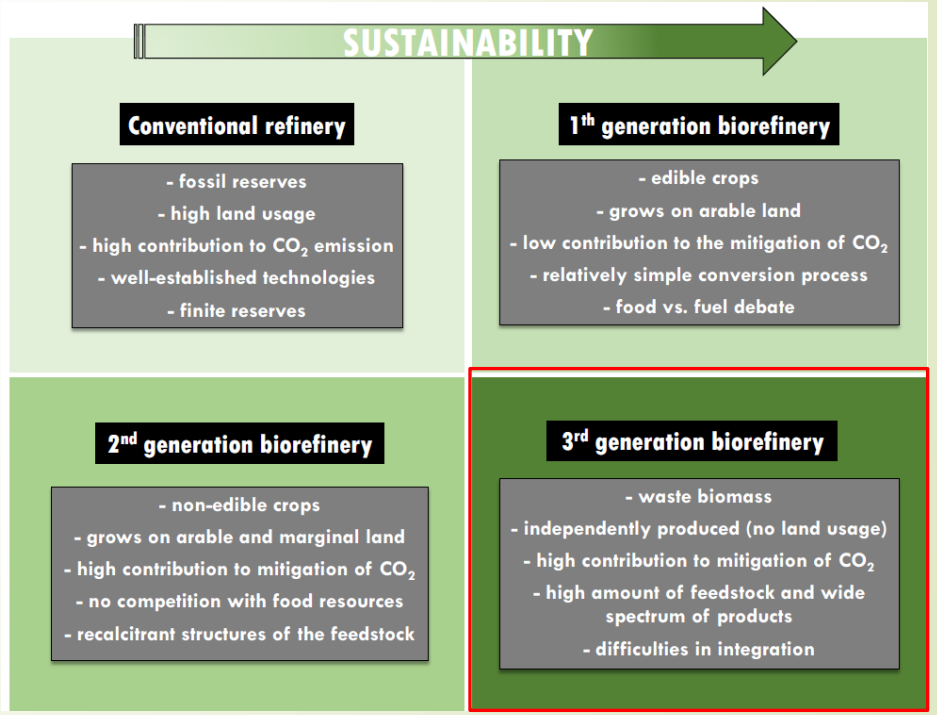
Climate change and resource depletion → need for the transition to a circular economy model (EU Green Deal)→ waste recovery and conversion into high-added value compounds (volatile fatty acids, VFAs) and energy (biogas, H_2).

- Main waste streams of the urban metabolism: sewage sludge (SS) and food waste (FW)
- In the EU: 13 mln tonn of SS (dry matter)

  78 mln tonn of FW

Third generation biorefinery:

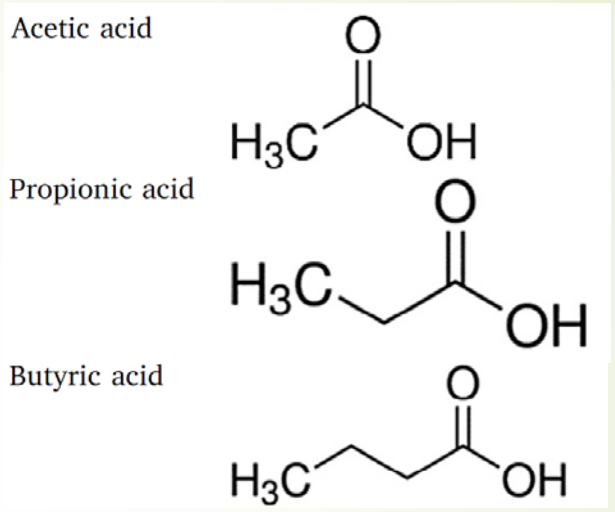
- Substrate pretreatment (hydrodynamic cavitation)
- Fermentation process→ VFAs and H_2
- Anaerobic digestion process→ biogas



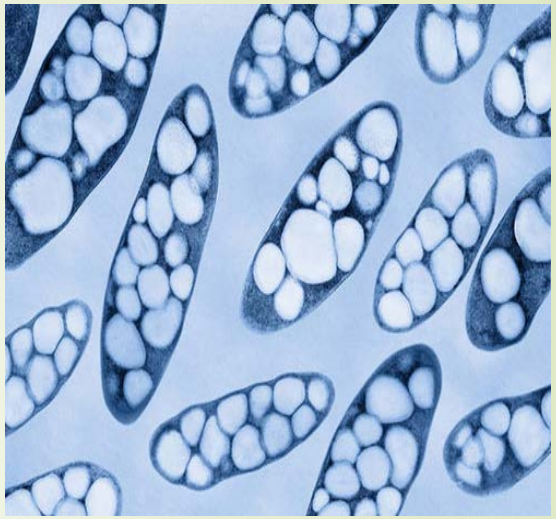
Evolution of the biorefinery (Strazzera, 2020).

VFAs production

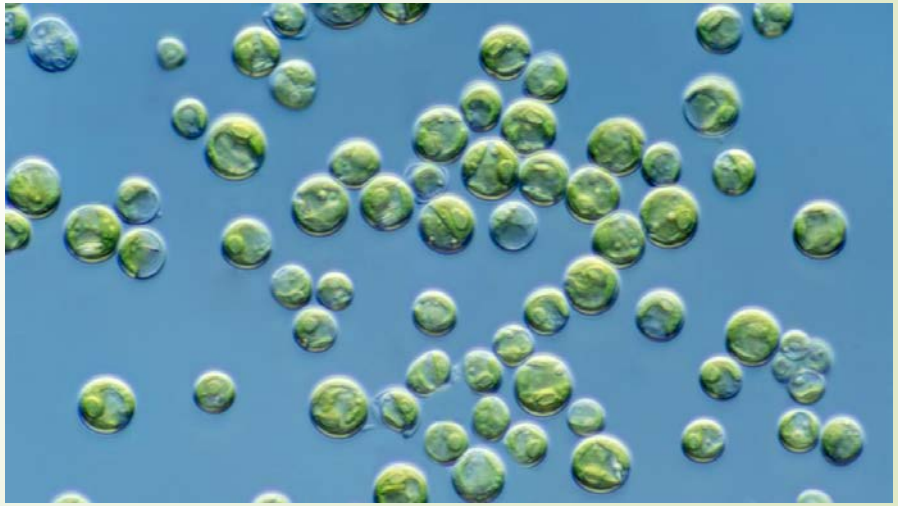
- Aliphatic monocarboxylate compounds C_2-C_7
- Global market: 13 mln tonn/year, 8 mld $/year (market value)
- Various applications in the food, cosmetics, textile, bioenergy, chemical and pharmaceutical industry
- At present, 90% is produced from petrochemical compounds



Volatile fatty acids (Atasoy et al., 2018).



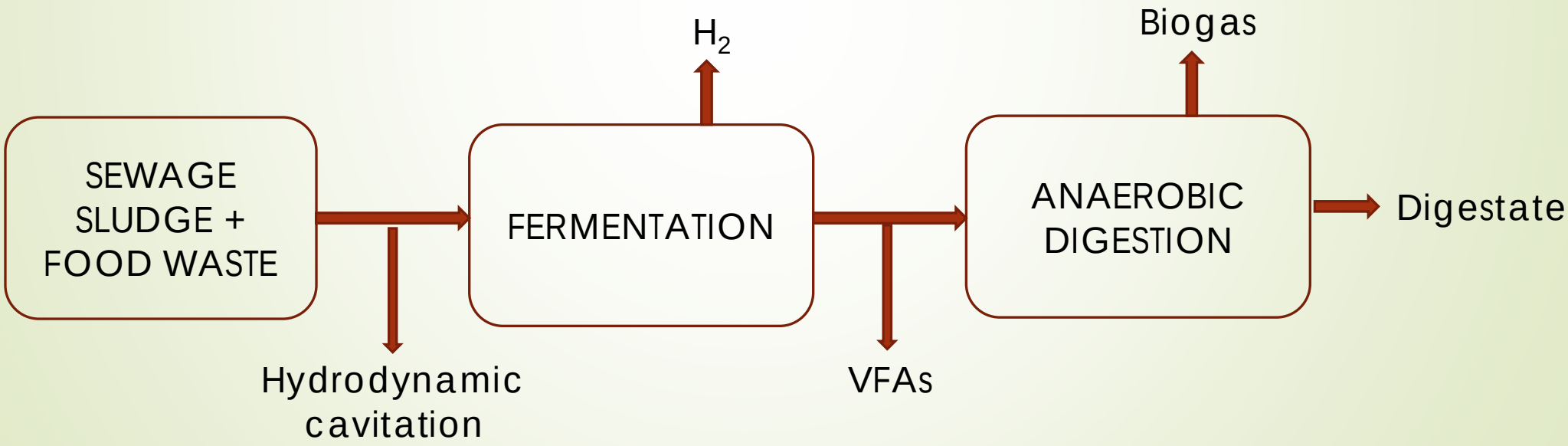
PHA granules. Retrieved from: plastix.it



Chlorella vulgaris. Retrieved from: micropia.nl

Aim of the research

Valorisation of the two main waste streams of the urban metabolism, sewage sludge and food waste, by transforming them into high-added value compounds (VFAs) and energy (biogas) through a combined process of fermentation and anaerobic digestion.



Specific targets

- Assessment of the disgregation of the substrate (visually and through chemical-physical characterization)
- Comparison of VFAs yields in batch tests and semi-continuous operation mode ($gCOD_{VFAs}/gVS_{(0)}$ and VFAs profile)
- Assessment of the biochemical methane potential (BMP)

Green Propulsion Laboratory, Veritas s.p.a.

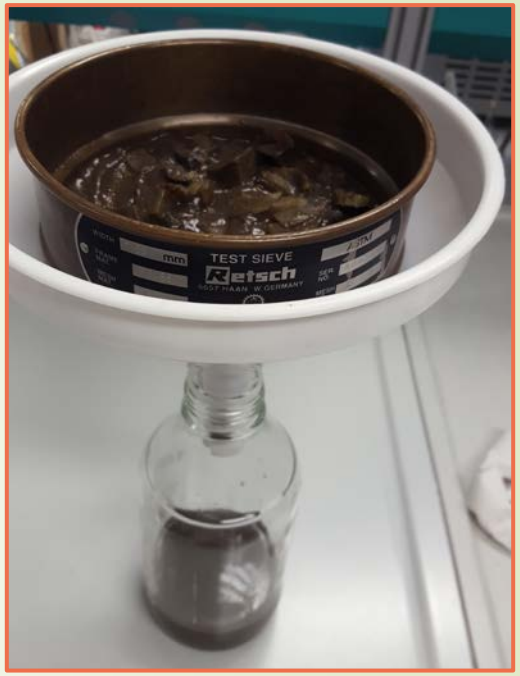
Materials and methods

Cavitation tests

Mixture composition:

70% sewage sludge, **30%** food waste (v/v)

Hydrodynamic cavitator, GP Lab



First cavitation test

- -23% TS, - 22% TVS
- + 39% sCOD
- 1,71 ± 0,21 $gCOD_{VFAs}/L$ → 6,80 ± 0,07 $gCOD_{VFAs}/L$

Second cavitation test

- -39% TS, -43% TVS
- + 43% sCOD
- 1,78 ± 0,03 $gCOD_{VFAs}/L$ → 4,8 ± 0,04 $gCOD_{VFAs}/L$

NOT CAVITATED

CAVITATED

Experimental design- fermentation process

Working conditions:

- Mesophilic temperature (37°C)
- CSTR reactors with mechanical stirring (14 rpm)
- V= 4 L
- Uncontrolled pH

Batch test

Parameter	Unit	First batch		Second batch	
		cavitated	not cavitated	cavitated	not cavitated
Organic loading (OL) tCOD	kg_{tCOD}/m^3	21,4	22,4	33,4	34,8
Organic loading (OL) VS	kg_{TVS}/m^3	11,9	14,9	18,8	24,5
Food/microrganisms (F/M) tCOD	kg_{tCOD}/kg_{TVS}	2,86	2,95	9,51	9,92
Food/microrganisms (F/M) VS	kg_{TVS}/kg_{TVS}	1,59	1,96	5,35	6,98
Inoculum	volume % on the total	60	60	34	34

Semi-continuous process

Parameter	Unit	Cavitated	Not cavitated
OLR	kg_{TVS}/m^3d	8	8
OLR	kg_{tCOD}/m^3d	14,2	11,4
HRT	d	5	6,6

Experimental design-BMP tests

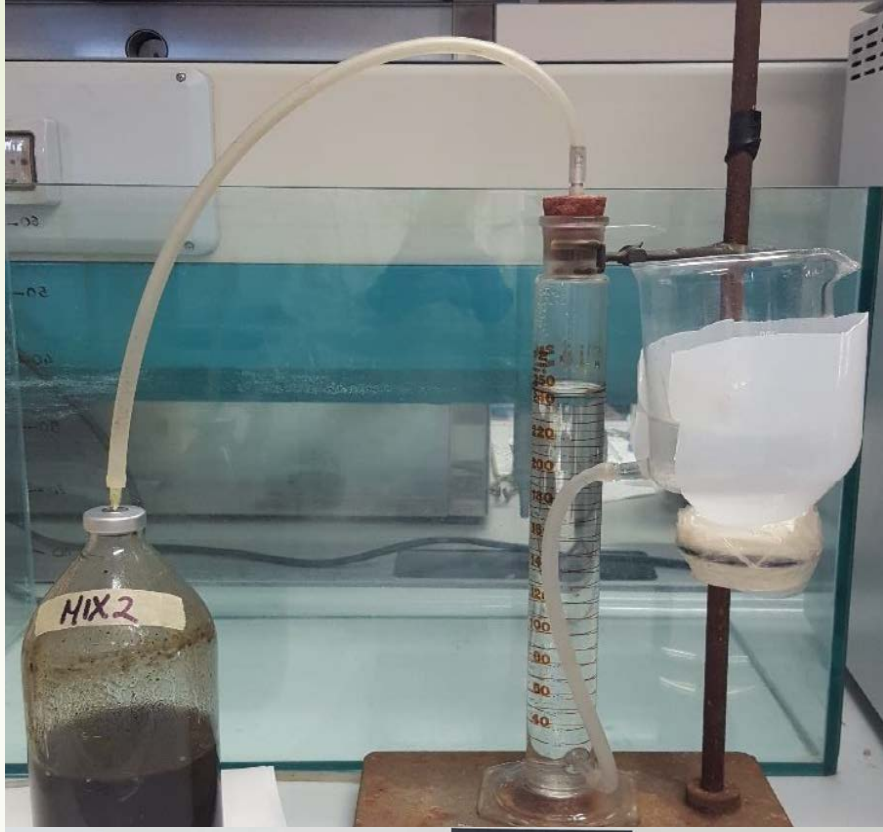
Batch tests

Parameter	Unit	Sewage sludge	Vegetable scraps	Cavitated mixture	Not cavitated mixture	Fermentation effluent (cavitated)	Fermentation effluent (not cavitated)	Solid-rich fraction (cavitated)	Solid-rich fraction (not cavitated)
TQ inoculum	L	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
TVS inoculum	g	6,20	6,20	5,20	5,20	6,99	6,99	6,99	6,99
TVS substrate	g/kg_{TQ}	24,44 ± 0,15	82,38 ± 5,22	28,38 ± 0,02	35,46 ± 1,11	12,55 ± 1,00	19,64 ± 1,26	120,49 ± 1,38	106,16 ± 0,30
TQ substrate	g	92,55	27,51	88,26	66,23	199,19	127,29	20,74	23,64
TVS substrate	g	2,26	2,27	2,50	2,35	2,50	2,50	2,50	2,51
F/M	VS/VS	0,36	0,37	0,48	0,45	0,36	0,36	0,36	0,36
F/M	$kg_{tCOD}/kgVS$			0,85	0,76	0,85	0,74		
OL	kg_{TVS}/m^3	4,52	4,53	5,00	4,70	5,00	5,00	5,00	5,02
OL	kg_{tCOD}/m^3			8,88	7,87	11,84	10,27		

Working conditions:

- Mesophilic temperature (42°C)
- Working volume= 0,5 L
- Glass bottles mixed manually

Results



Semi-continuous fermentation process- Yields

- **$[VFAs]_{max}$**

Cavitated: 12,94 ± 0,63 $gCOD_{VFAs}/L$, **pH**= 5,508

Not cavitated: 18,23 ± 0,51 $gCOD_{VFAs}/L$, **pH**= 5,354

- **Yields**

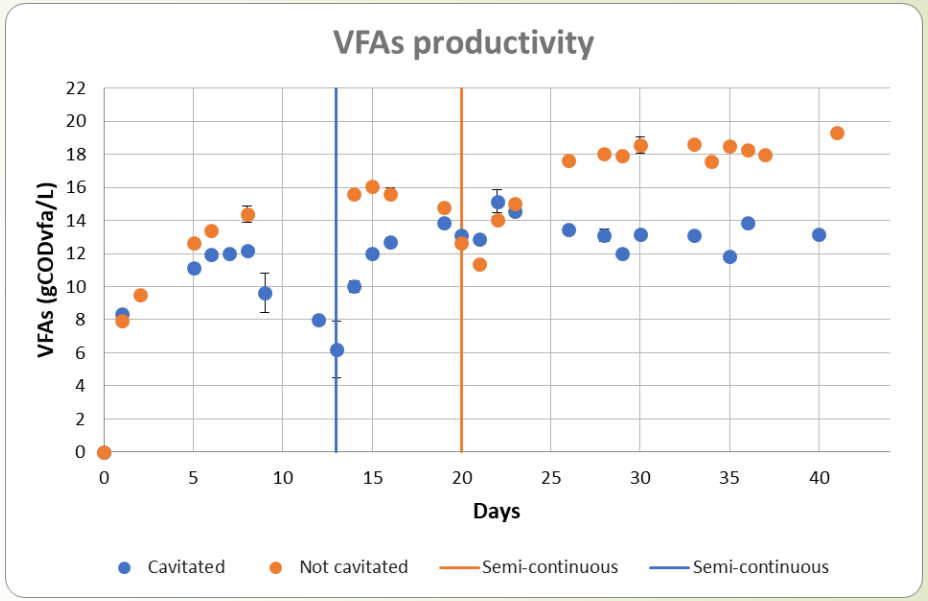
Cavitated: 0,53 ± 0,07 $gCOD_{VFAs}/gVS_{(0)}$

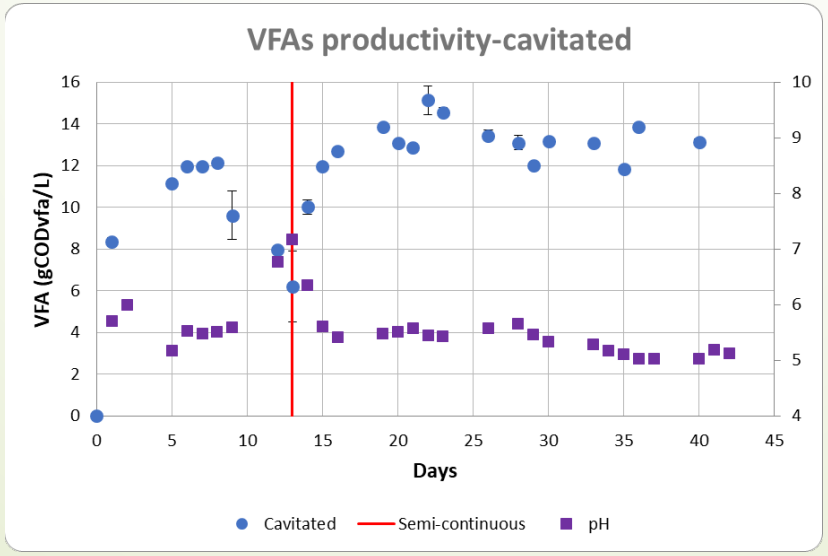
Not cavitated: 0,52 ± 0,06 $gCOD_{VFAs}/gVS_{(0)}$

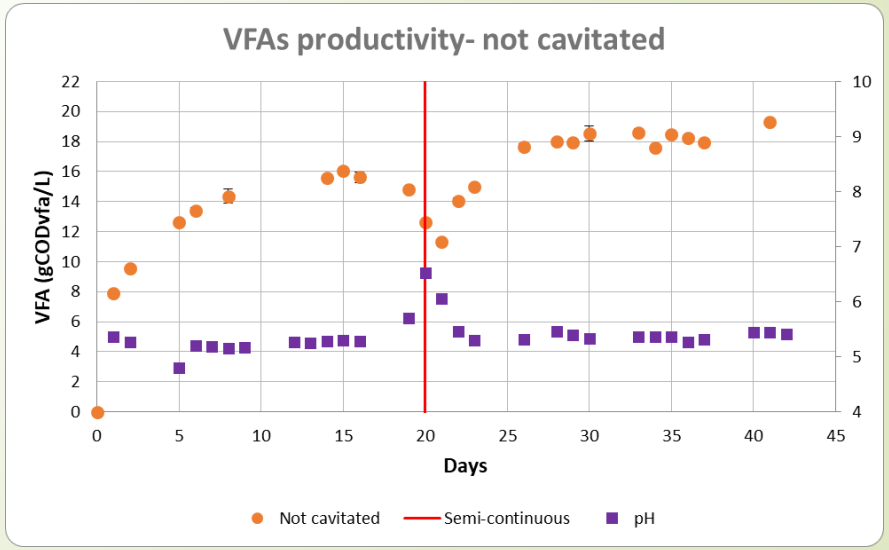
- **Steady state**

Cavitated: 3,8 HRT

Not cavitated: 2,6 HRT





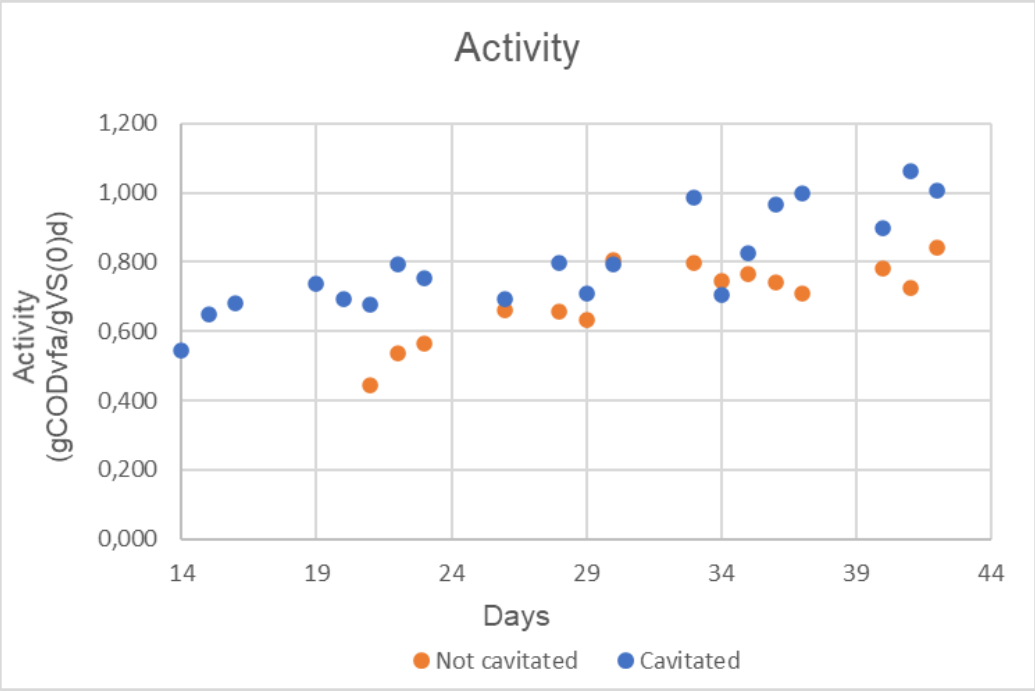


Semi-continuous fermentation process- Activity

- **Activity**

Cavitated: 1,01 ± 0,01 $gCOD_{VFAs}/gVS_{(0)}*d$ → **+20%**

Not cavitated: 0,84 ± 0,01 $gCOD_{VFAs}/gVS_{(0)}*d$

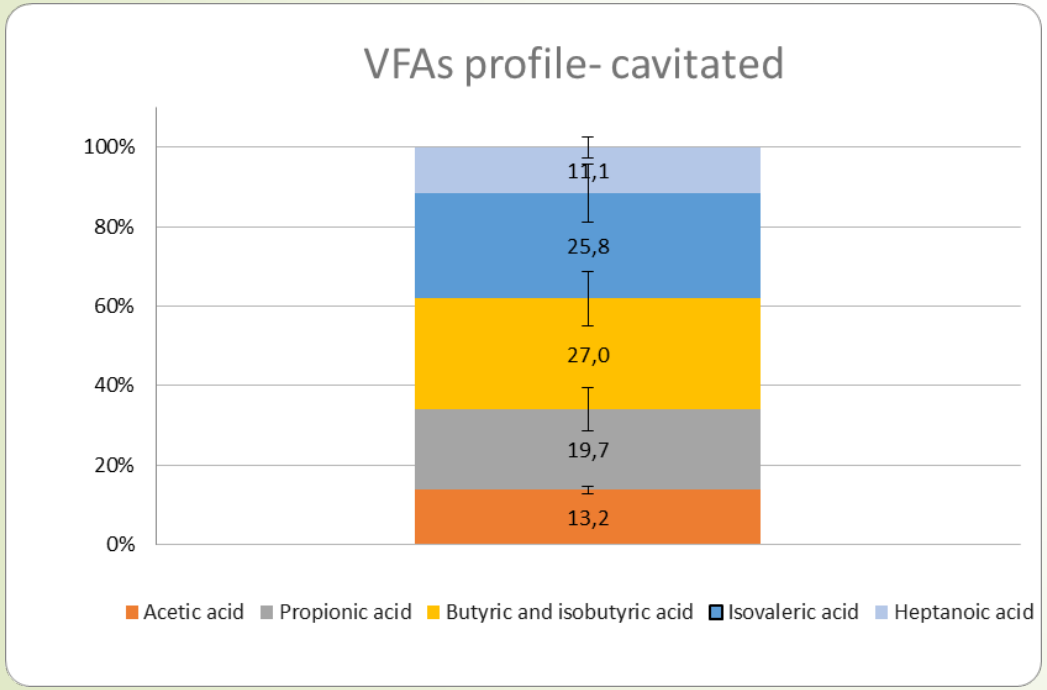


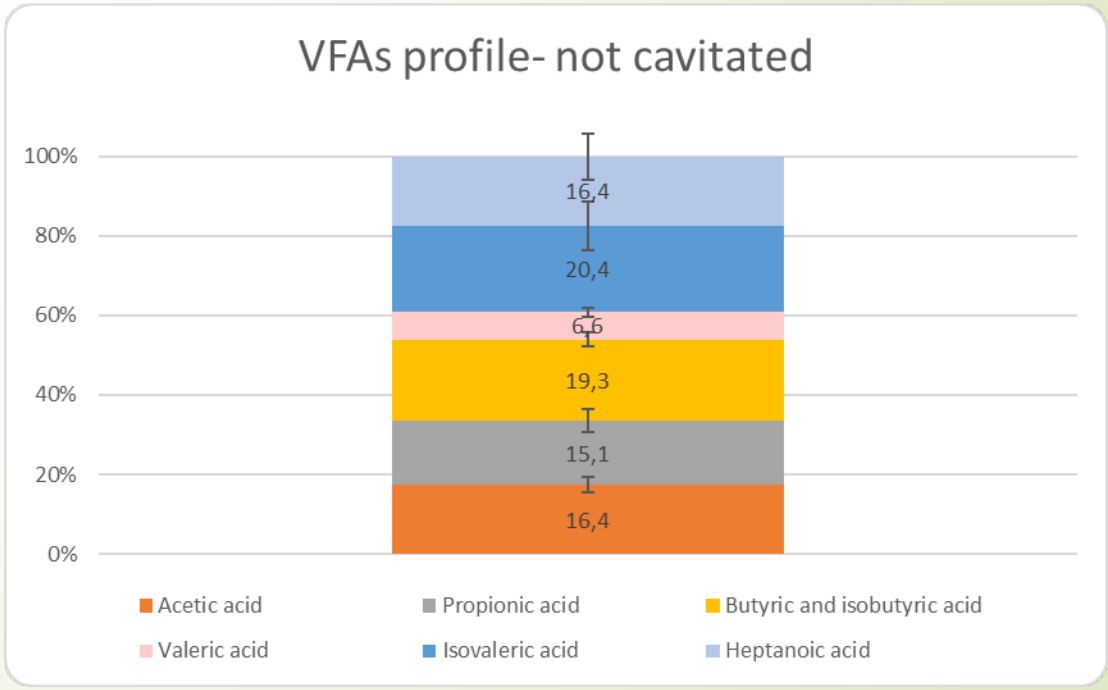
Semi-continuous fermentation process- VFAs profile

- $[C_3/(C_3+C_2)]_{VFAs}$

Cavitated: 0,53 ± 0,04

Not cavitated: 0,48 ± 0,04

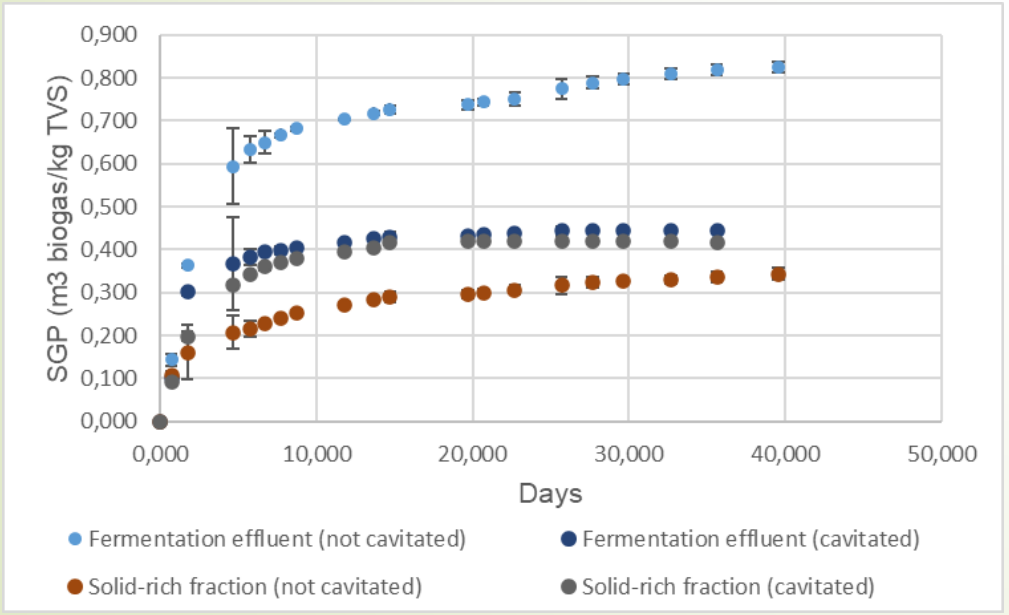


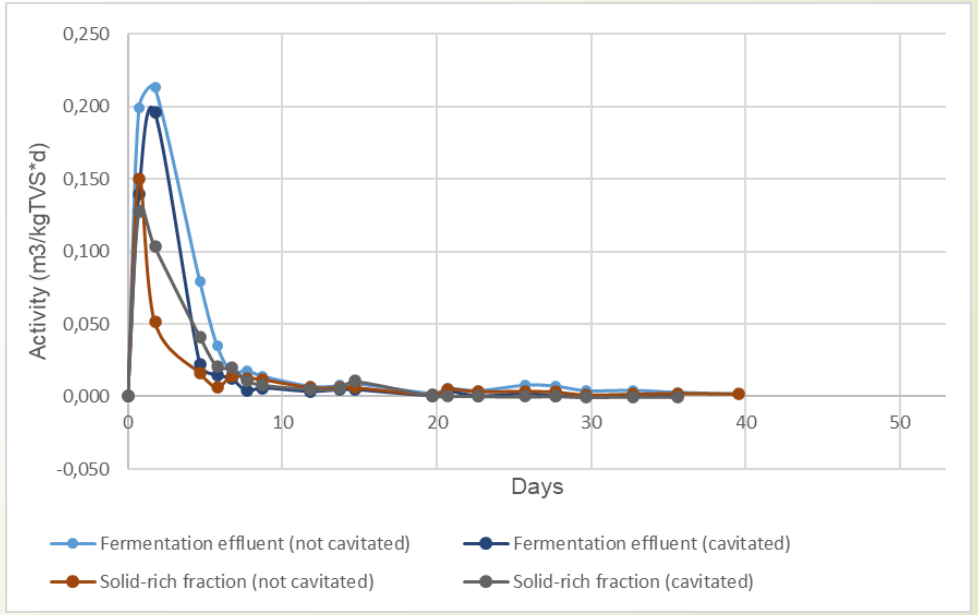


Results

BMP and activity of the fermentation effluent

	Unit	Fermentation effluent (cavitated)	Fermentation effluent (not cavitated)	Solid-rich fraction (cavitated)	Solid-rich fraction (not cavitated)
SGP	m^3biogas/kg_{TVS}	0,445	0,825	0,418	0,343
SMP	m^3CH_4/kg_{TVS}	0,267	0,495	0,251	0,206
Confidence		0,001	0,012	0,001	0,014
Test duration	days	36	40	36	40





Conclusions

Hydrodynamic cavitation processes

- Increase of the sCOD, reduction of TS and TVS
- 20% increase of the activity in the semi-continuous fermentation process
- Stable VFAs production, even with low HRT (3,3 d)

Fermentation processes

- Good yields respect to comparable studies in literature
- Stable and robust process

BMP tests

- Confirm the process feasibility from an energetic point of view

Team

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Thanks for your attention