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Polyhydroxyalkanoates production using the liquid fraction of hydrolysed municipal organic waste

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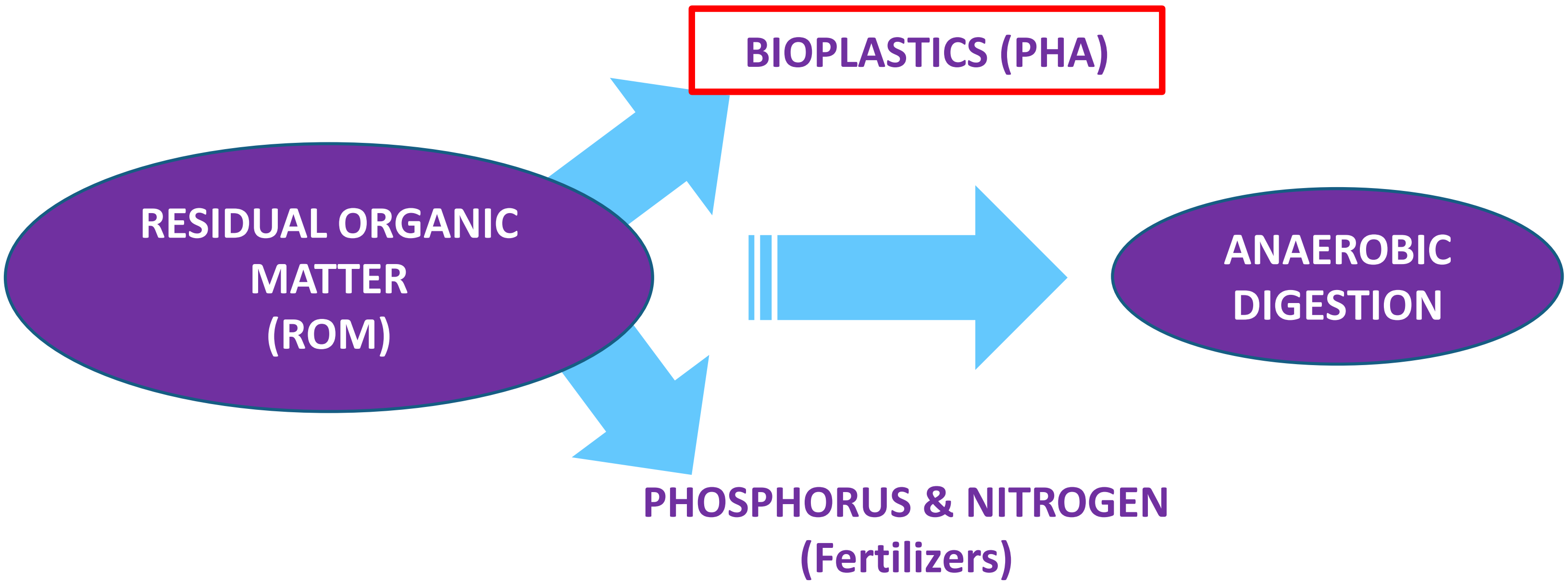
LAYOUT OF THE PRESENTATION

- **INTRODUCTION**
  - PHA-BASED BIOPLASTICS
  - PRODUCTION OF BIOPLASTICS FROM RESIDUAL ORGANIC MATTER (ROM)
  - PROPOSED PHA PRODUCTION SYSTEM
- **LAB-SCALE RESULTS AND DISCUSSION**
  - FERMENTATION OF ROM
  - SELECTION OF PHA ACCUMULATING BIOMASS
  - PHA ACCUMULATION
- **CONCLUSIONS**

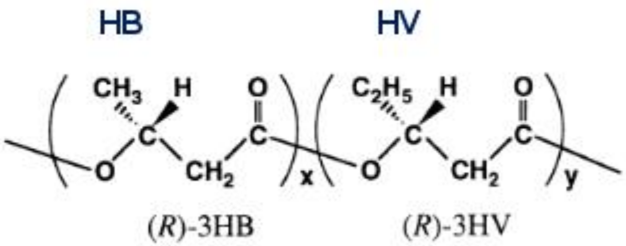
Introduction: PHA-based bioplastics

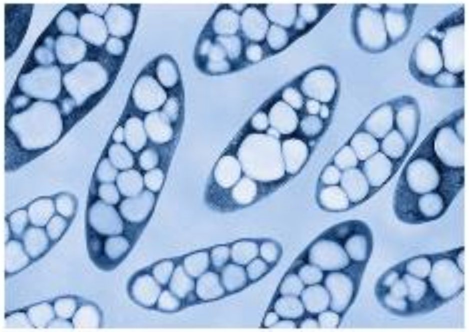
- New trends in waste management: **CIRCULAR ECONOMY**



Introduction: PHA-based bioplastics: PHA

Polyesters produced by bacteria from the **degradation of biodegradable organic matter** as a mechanism to store carbon and energy.





PHA have **thermoplastic properties** which are **similar to the ones of conventional polyolefin** (many possible applications) with the advantages of being **biodegradable, biocompatible and renewable.**

Introduction: PHA-based bioplastics: PHA

- PHA can be produced from different sources of biodegradable organic carbon, for example, **Volatile Fatty Acids (VFA).**

- PHA market is well established and it has a **high expansion potential.**

2016		**2018**
2.000.000 t PHA	→	Almost 7.000.000 t PHA

Forecast INSTITUTE FOR BIOPLASTICS AND BIOCOMPOSITES (2016)

- Production of bioplastics from ROM:
    - **Alternative** to the production from **dedicated crops** (corn, rice, barley, …).
    - **Lower production costs** (avoiding raw materials costs and use of pure cultures).

Introduction: PHA production from ROM

The production of PHA from wastes needs 3 steps (Reis et al., 2011):

1) FERMENTATION OF THE ORGANIC SUBSTRATE

Production of Volatile Fatty Acids (VFA)

2) SELECTION OF PHA-ACCUMULATING BIOMASS

Establishing in a bioreactor the appropriate conditions to favour the growth and enrichment of PHA bacteria

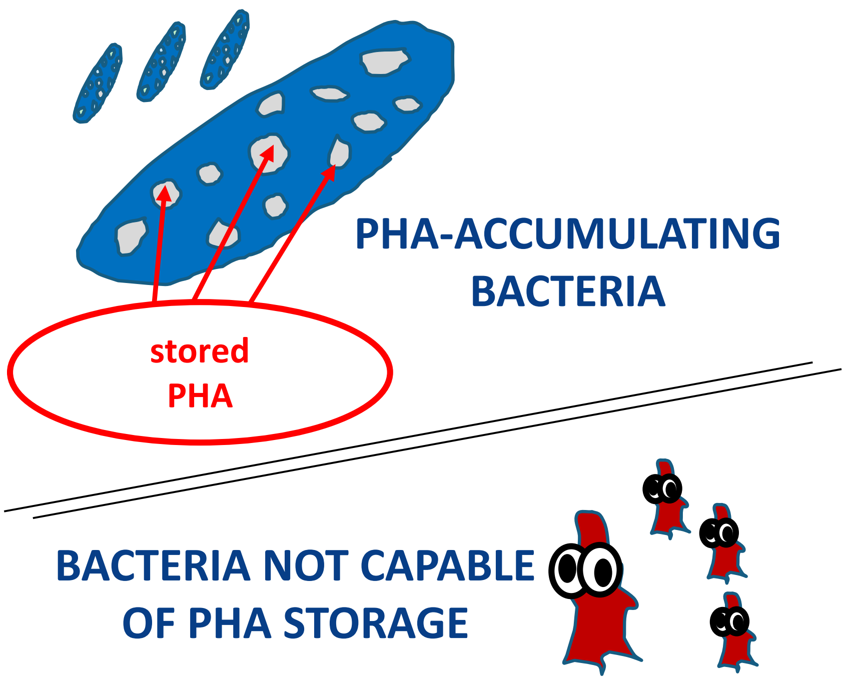
3) PHA ENRICHMENT

Operate a second bioreactor under the optimum conditions to increase the concentration of PHA in the biomass

Introduction: PHA production from ROM

2) SELECTION OF PHA-ACCUMULATING BIOMASS

Use of Feast/Famine cycles to select and enrich the biomass in PHA-accumulating bacteria



FAMINE

VFA VFA

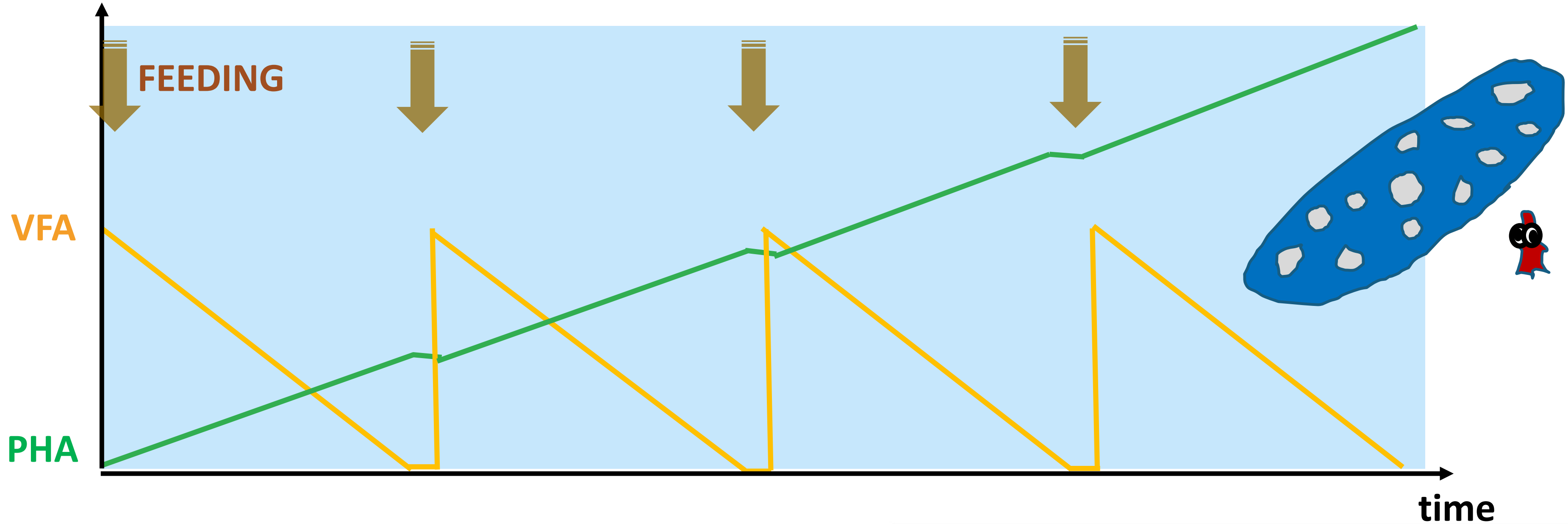
VFA VFA VFA

VFA VFA

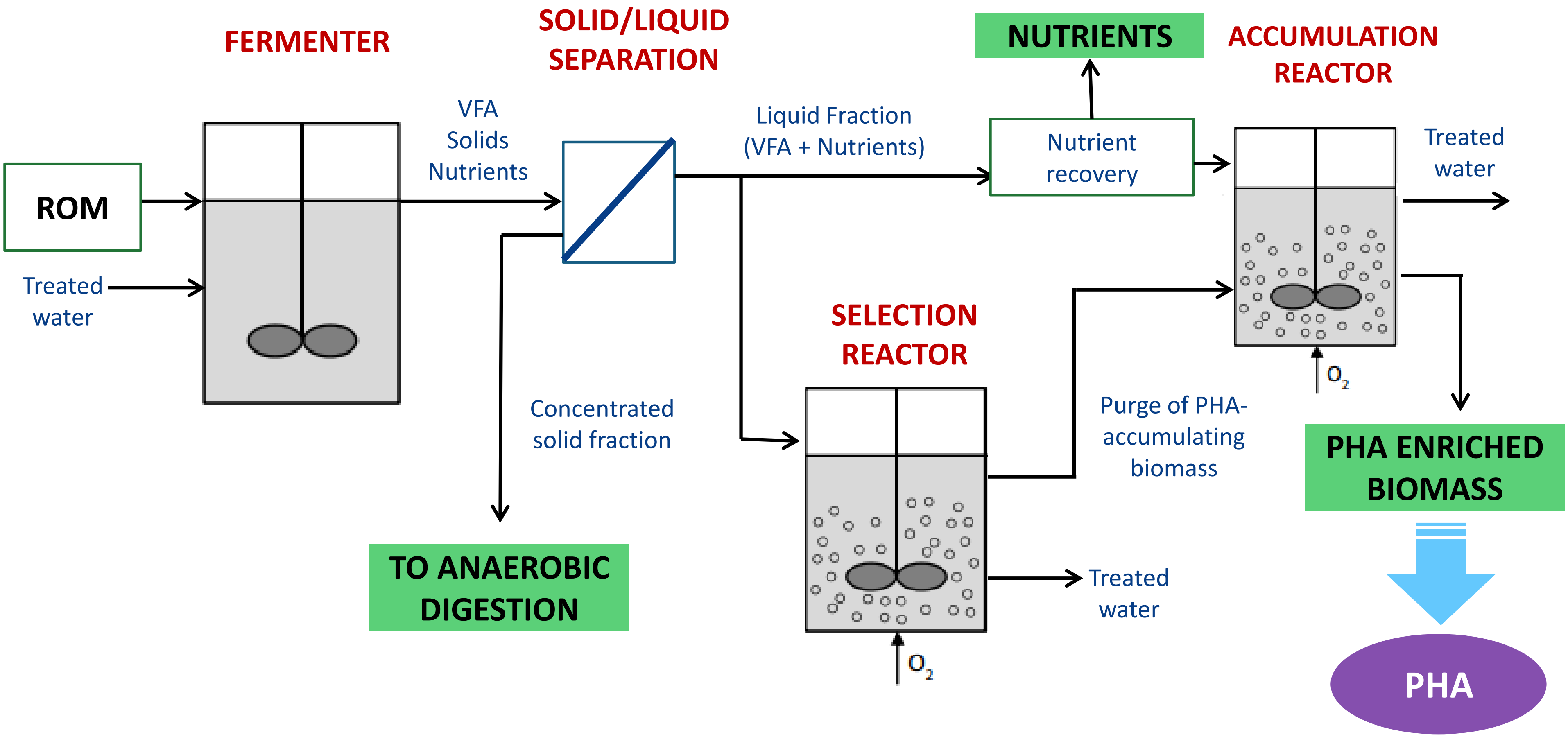
Introduction: PHA production from ROM

3) PHA ENRICHMENT

PHA storage in the biomass using feed on demand strategies



Introduction: PHA production from ROM



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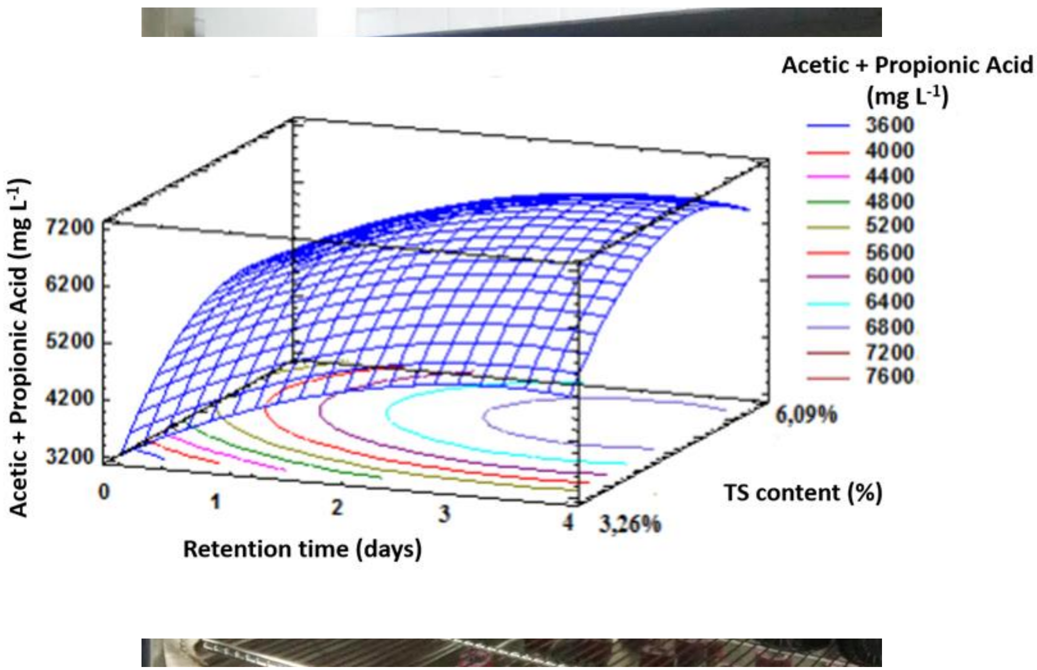
Results: Fermentation of ROM

Batch tests with ROM



Concentration of Total Solids (TS):
3.3 – 4.4 – 5.6 – 6.1 – 8.1 %

Time of the tests:
5 d

OPTIMUM CONDITIONS:

TS: 5.4%

Retention time: 3.4 d

T: 37 °C

Results: Fermentation of ROM

Continuous reactor

Volume: 4-5 L

Mechanical stirring

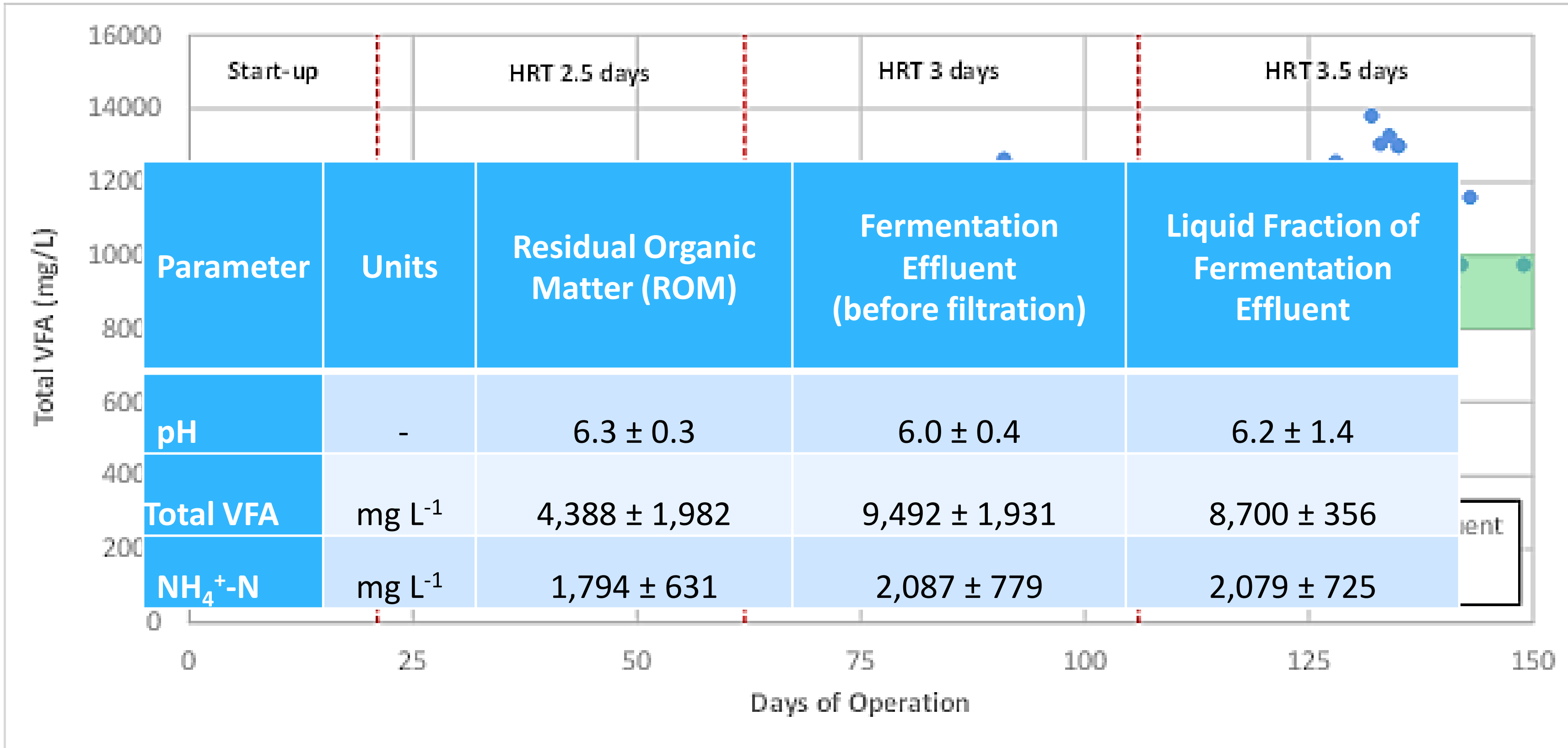
Temperature: 37 °C

Inoculated with anaerobic digester effluent

Initial HRT: 2.5 d (wash out of methanogens)

Results: Fermentation of ROM

Fermenter of ROM



Parameter	Units	Residual Organic Matter (ROM)	Fermentation Effluent (before filtration)	Liquid Fraction of Fermentation Effluent
pH	-	6.3 ± 0.3	6.0 ± 0.4	6.2 ± 1.4
Total VFA	mg L^{-1}	4,388 ± 1,982	9,492 ± 1,931	8,700 ± 356
NH_4^+-N	mg L^{-1}	1,794 ± 631	2,087 ± 779	2,079 ± 725

HRT 2.5-3.5 d

Temperature 37 °C

Results: Selection of PHA-accumulating biomass

Selection reactor

- Volume 3L
- Mechanical stirring
- Air supply
- Ambient temperature

pH and DO online measurement

3 peristaltic pumps to control: HRT, SRT and feeding

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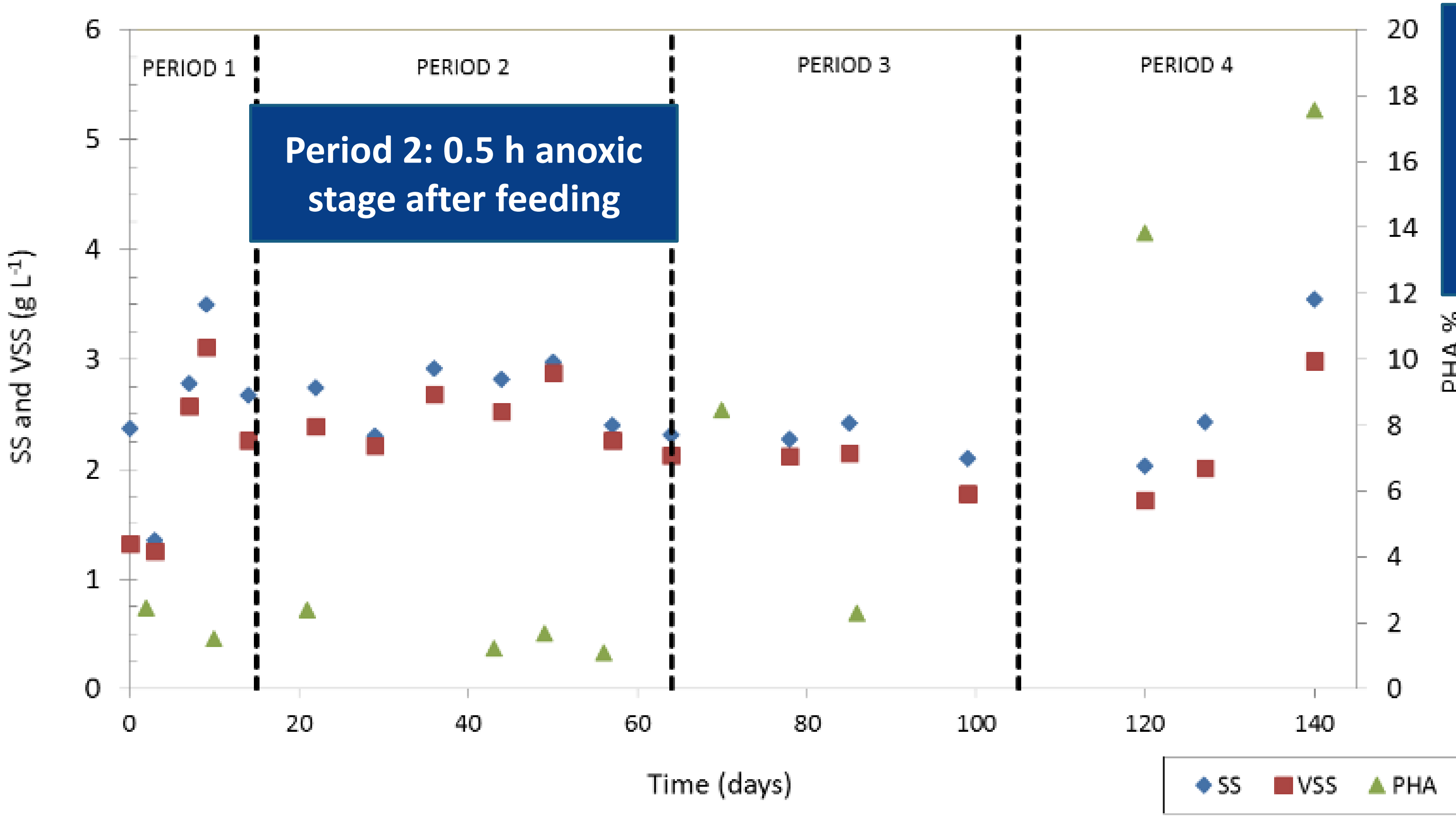
Results: Selection of PHA-accumulating biomass



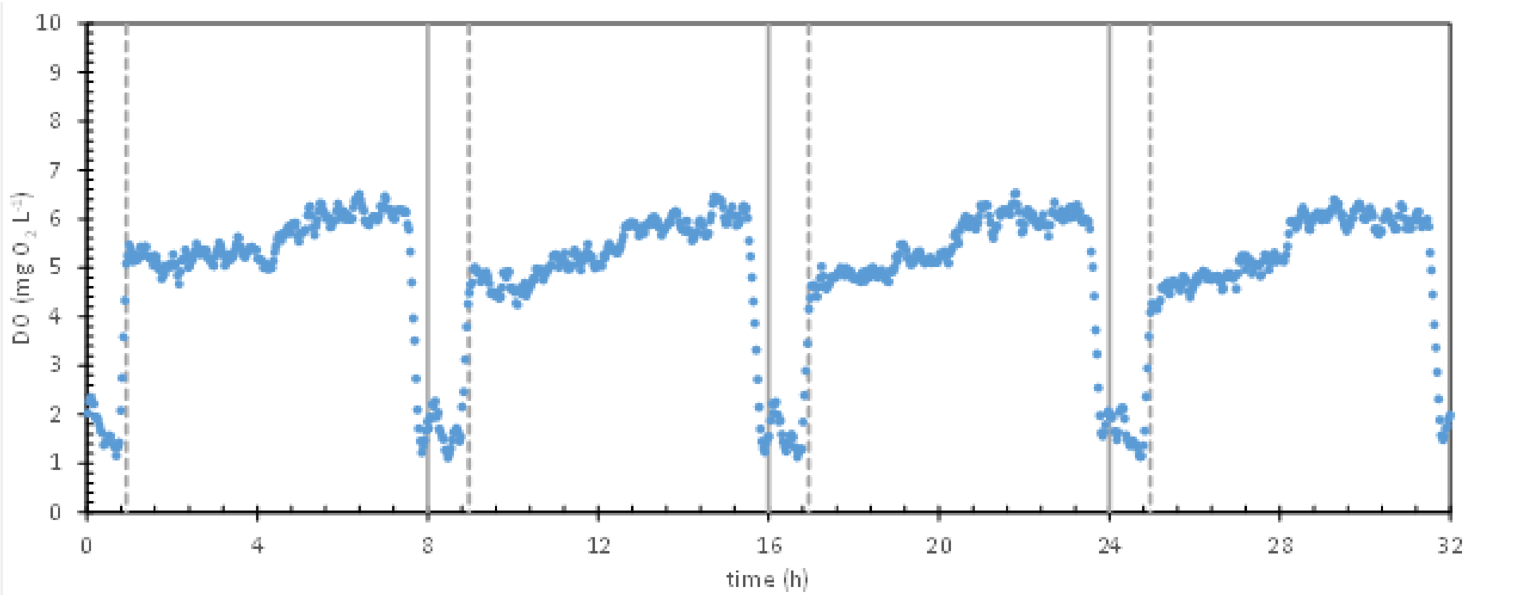
Period 2: 0.5 h anoxic stage after feeding

Period 4: undiluted hydrolysed ROM HRT 6d SRT 20d

Periods 1 to 3:
50% diluted hydrolysed ROM + acetic acid, 6 g VFA/L
HRT 7.5d, SRT 17d
Cycle: 7 h air, 0.5 h mixing, 0.5 h settling and effluent withdrawal

Feast/Famine 0.15-0.21
VFA removal 99%

Results: Selection of PHA-accumulating biomass: Period 4, undiluted hydrolysed ROM



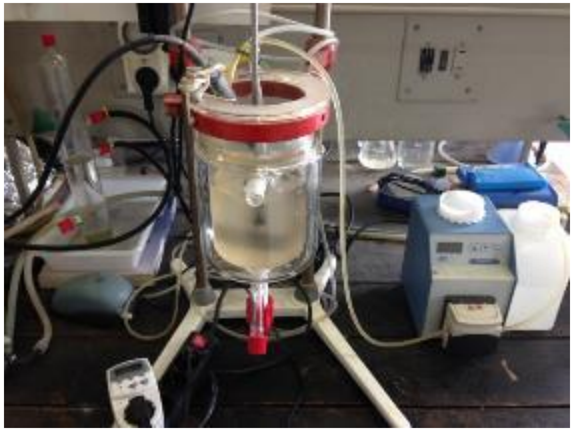
Parameter		Average Value	Range Value	Units
Cycle duration		8	-	h
	Feeding (with mixing)	2	-	min
	Aeration + mixing	432	-	min
	Mixing (no aeration)	30	-	min
	Settling	15	-	min
	Effluent withdrawal	1	-	min
OLR		1.29	0.90-1.67	g VFA (L day)$^{-1}$
% VFA removal		>99	-	%
HRT		6	-	days
SRT		20	-	days
TSS		3.02	2.03-3.54	g SS L^{-1}
VSS		2.47	1.72-2.99	g VSS L^{-1}
Feast/Famine time ratio		0.15	0.14-0.15	-
% PHA in the purged biomass		15.7	13.8-17.6	% (on VSS basis)

Cycle 8h

OLR
1.3 kg VFA/(m^3 d)

Feast/Famine 0.15

Results: PHA accumulation



Batch tests

Volume of the reactor: 0.7L

Inoculum: 100 mL biomass purged from the selection reactor per batch (collected mainly during periods 2, 3)

Fermentation Liquid Concentration	10%	33%	100%	
Total VFA	6050 ±705	5839 ±1345	5722 ±1512	mg L^{-1}
Acetic	99.2	64.6	32.0	% of Total
Propionic	0.2	14.8	39.1	% of Total
Isobutyric	0.0	5.3	11.4	% of Total
Butyric	0.2	5.3	13.2	% of Total
NH_4^+-N	6.9 ±4	725.3*	2,198 ±716	mg N L^{-1}
N/COD	0.46	49.8	114.3	mg g^{-1}
pH	5.7 ±0.3	5.7 ±0.5	6.2 ±1.4	-

*Calculated based on NH_4^+-N concentration in 100% fermentation liquid

Results: PHA accumulation

- Feeding each 4 hours.
- Total time of each batch: 24 h
- PHA yield decreased with the increased concentration of fermentation liquid: NH_4^+

Highest PHA yield = **38% (VSS basis)**

Fermentation Liquid Concentration		10%	33%	100%	
OLR		1.9 ±0.35	1.86 ±0.56	1.86 ±0.58	kg VFA $(m^3 day)^{-1}$
Initial F:M		0.63 ±0.18	0.98 ±0.11	0.93 ±0.16	g VFA g^{-1} TSS
VFA removal		58 ±25	50	44 ±13.24	%
TSS					g L^{-1}
	Initial	0.74 ±0.29	0.46 ±0.10	0.49 ±0.09	
	Final	1.29 ±0.62	1.15 ±0.13	1.54 ±0.09	
VSS					g L^{-1}
	Initial	0.62 ±0.30	0.42 ±0.07	0.47 ±0.09	
	Final	1.18 ±0.68	1.07 ±0.16	1.42 ±0.08	
PHA					% (on VSS basis)
	Initial	2.3 ±0.2	7.5 ±9.0	6.2 ±3.9	
	Final	**37.5 ±6.3**	**27.1 ±5.8**	**18.8 ±5.8**	

Conclusions

- The production of bioplastics from municipal organic waste can shift the management paradigm towards a more circular economy.

- About 8-10 g VFA/L have been obtained from the **fermentation** fermentation of ROM under the following conditions 5.4% solids, 37 °C, and 3.4 day HRT.

- The **selection reactor** was operated at a feast/famine ratio of 0.15, SRT of 20 days, and HRT of 6 days, achieving PHA-accumulating enriched biomass (up to 18% PHA on VSS basis).

- The **accumulation reactor** achieved a maximum PHA content of 38% (on VSS basis).

- Using the liquid fraction of fermented ROM as substrate in the PHA-accumulation phase resulted in reduced PHA production likely due to inhibition from high ammonia concentrations.

- ROM has been demonstrated as a feasible substrate for PHA production. Further process optimization and incorporation of nutrient recovery should be investigated.

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