Production of PHA with mixed cultures from fermented food waste rich in ammonia

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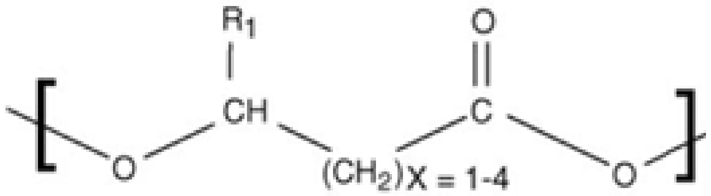
Why use food waste as feedstock?

- Food waste is food that was lost or discarded uneaten
- Around 1/3 of food is wasted annually; in EU alone, it amounts to 88 million tonnes alone.
- A significant portion of the food waste ends in landfills, which result in unwanted CH_4 emissions.

Solutions?

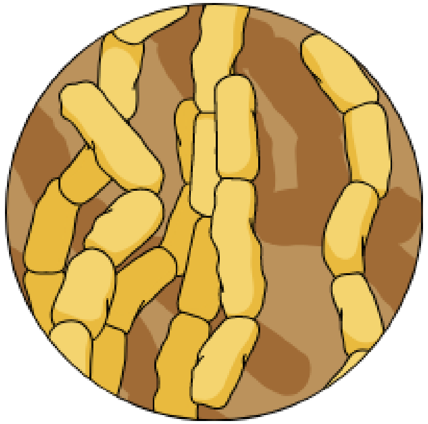
Why produce polyhydroxyalkanoates (PHA)?

- Biologically synthesized polyesther
- Biocompatible and completely biodegradable into CO_2 and H_2O
- Wide range of structural, mechanical and thermal properties



Sustainable alternative to conventional plastics

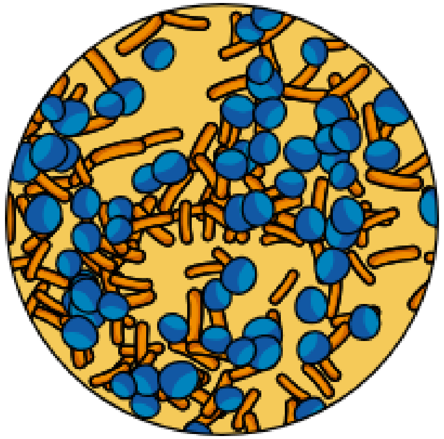
Why use mixed microbial cultures?



Volumetric productivity

Investment and operational costs

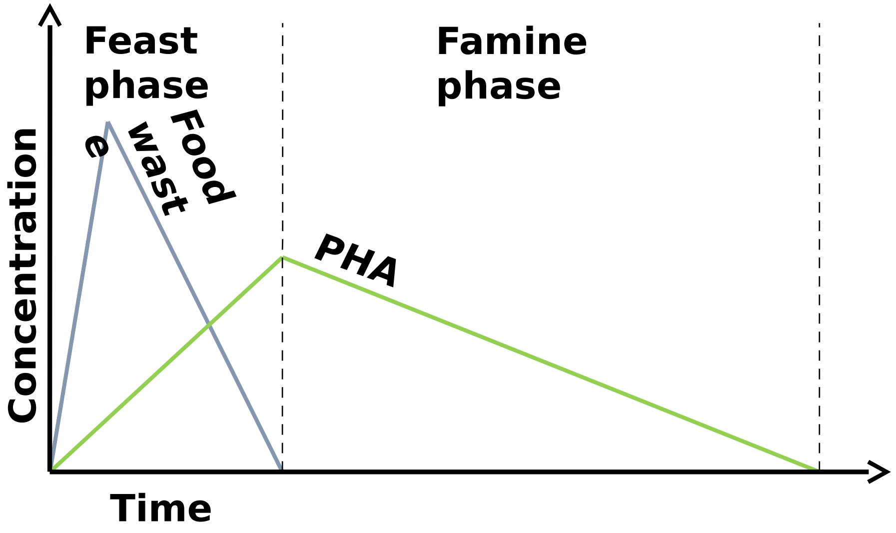
Sterile conditions



Investment costs

Sterile conditions

Volumetric productivity

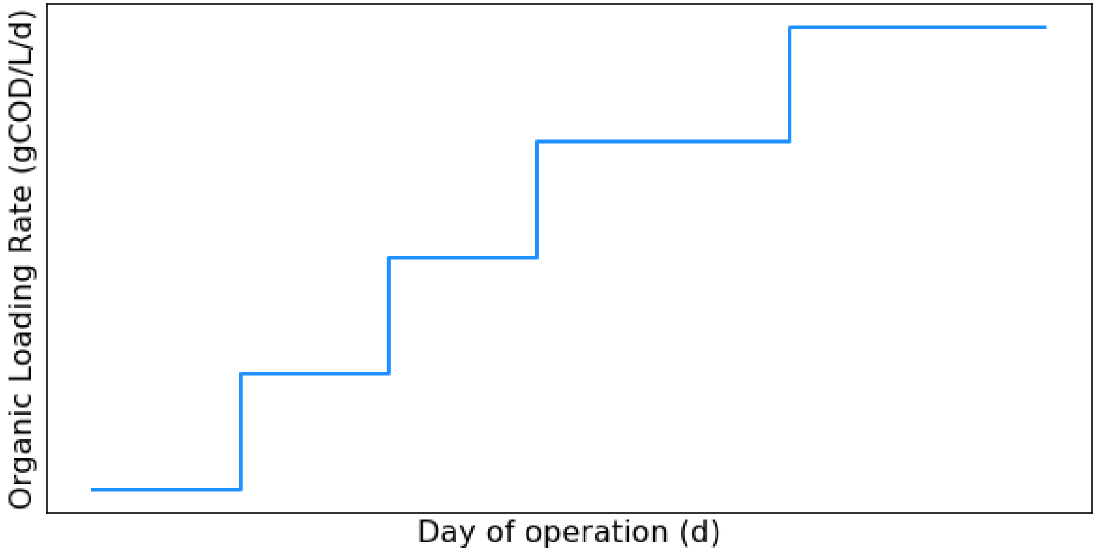


Approach

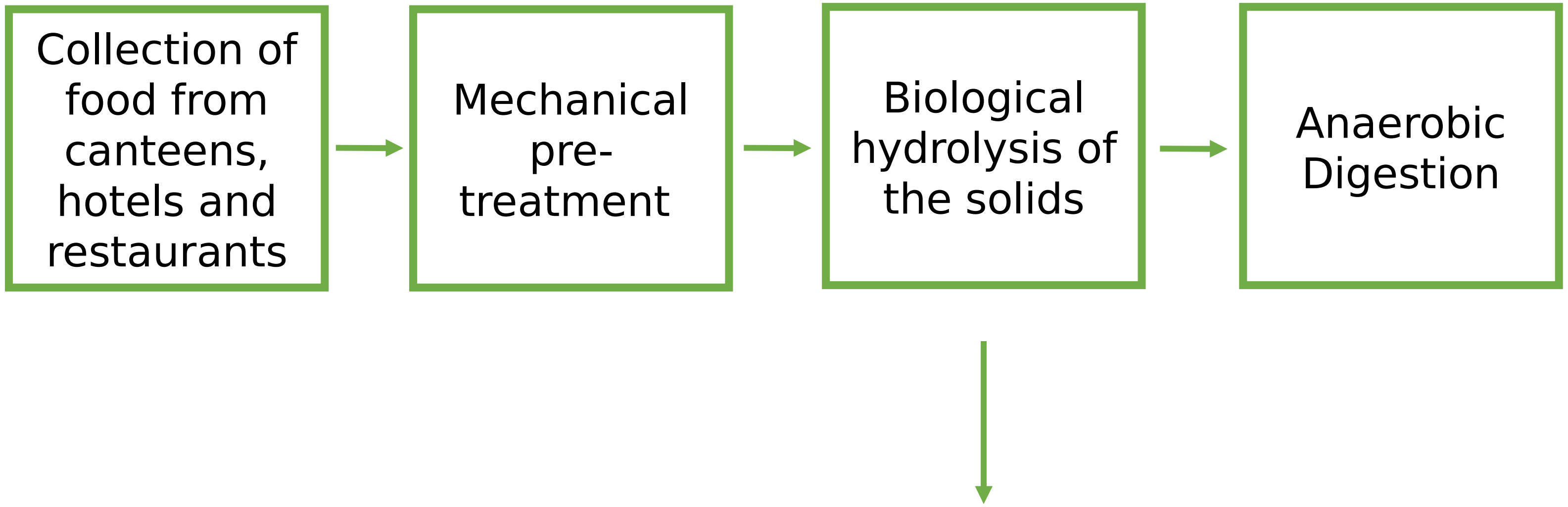
01 Characterize food waste and evaluate its feasibility as a feedstock for PHA production

02 Inoculate a SBR and select a culture with PHA accumulation capacity

03 Study the maximum accumulation capacity of the selected culture



Fermented food waste source



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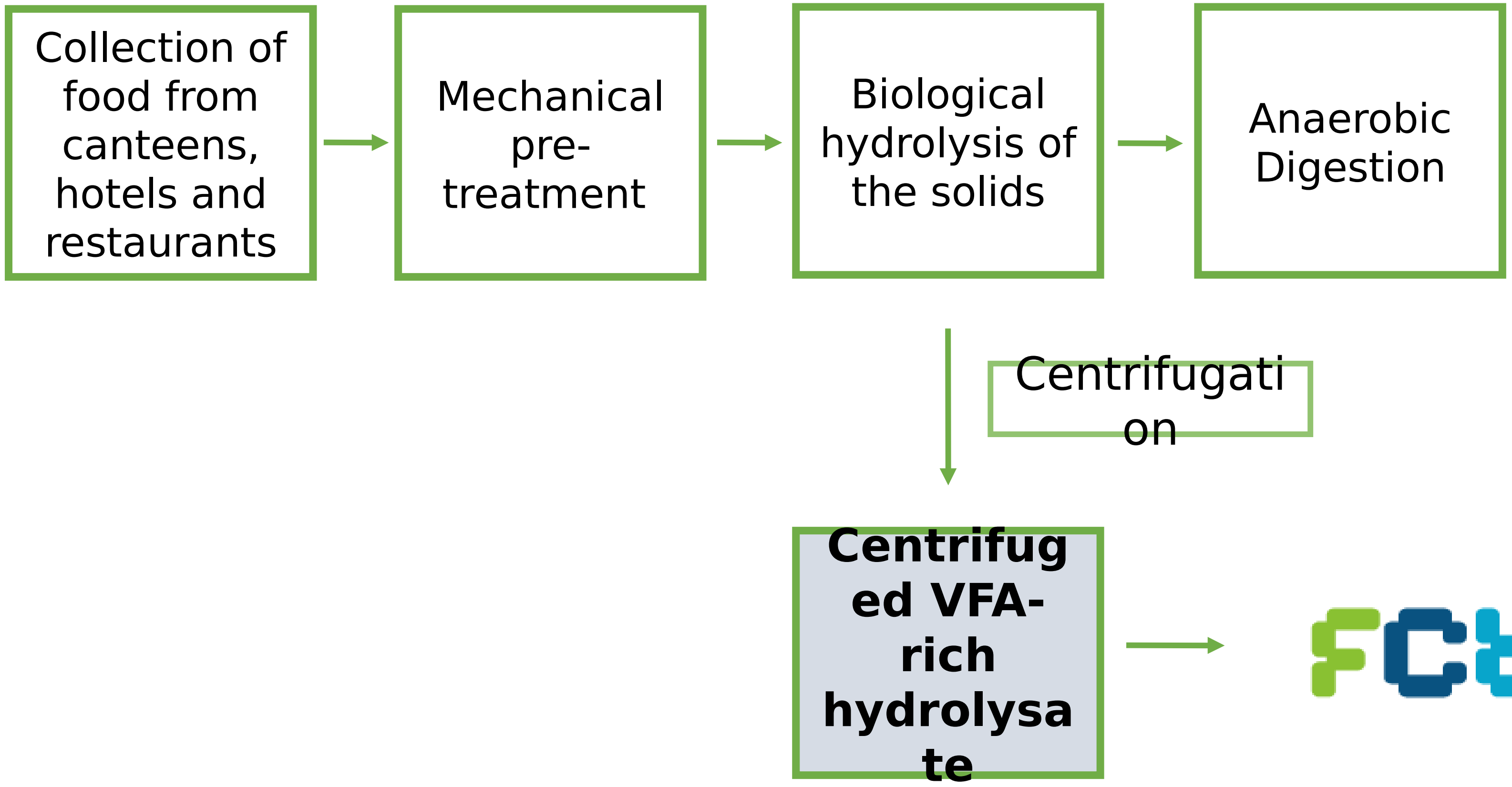
Food waste characterization

	Mean ± SD
COD_{TOT} (g L^{-1})	119 ± 0,28
COD_{SOL} (g L^{-1})	37,5 ± 1,34
TC (g L^{-1})	12,4 ± 0,01
TOC (g L^{-1})	12,3 ± 0,02
TOC (Cmmol L^{-1})	1026 ± 2,04
IC (mg L^{-1})	0,04 ± 0,01
$Prot_{TOT}$ (gCOD L^{-1})	14,9 ± 0,73
$Prot_{SOL}$ (gCOD L^{-1})	1,85 ± 0,04
CH_{TOT} (gCOD L^{-1})	7,53 ± 1,02
CH_{SOL} (gCOD L^{-1})	1,17 ± 0,38
FP (gCOD L^{-1})	31,9 ± 0,45
FP (Cmmol L^{-1})	898 ± 12,7
FP/COD_{SOL}	0,85 ± 0,02

	Mean ± SD
TS (g L^{-1})	62,4 ± 3,94
VS (g L^{-1})	53,6 ± 3,68
VS/TS (g g^{-1})	0,86 ± 0,005
$N-NH_3$ (gN L^{-1})	1,11 ± 0,01
$N-NO_3$ (gN L^{-1})	0
$N-NO_2$ (gN L^{-1})	0
Kejdhal (gN L^{-1})	3,2 ± 0,1
$N-NH_3$/Kejdhal	34,2 ± 1,2
$P-PO_4$ (mgP L^{-1})	331 ± 3,92
Nmol:Pmol	7,39 ± 0,15

- High COD content;
- High solid content, with plenty protein and carbohydrates (HC) content unfermented;
- High fermentation products (FP) to COD_{SOL} ratio;
- Nutrient-rich feedstock

Fermented food waste source



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SBR operation

	Mean ± SD
$gCOD_{TOT}$ L^{-1}	43.8 ± 5.47
$gCOD_{SOL}$ L^{-1}	31.4 ± 0.94
$gCOD_{FP}$ L^{-1}	25.9 ± 1.56
COD_{FP}/COD_{SOL}, %	82.7 ± 3.59
Cmmol L^{-1}	663 ± 39.7
Nmmol L^{-1}	143 ± 6.15
Pmmol L^{-1}	4.62 ± 0.42
N/C, %	21.3 ± 0.72
P/C, %	0.69 ± 0.05

Operating conditions	
Feedstock	Fermented Food Waste
OLR (gCOD L^{-1} d^{-1})	3.6 – 10.4 (gradual increase)
C:N:P (mol basis)	100:21:0.69
SRT (d)	4
Cycle length (h)	12
HRT (d)	1
T & pH	Uncontrolled
Volume (L)	2

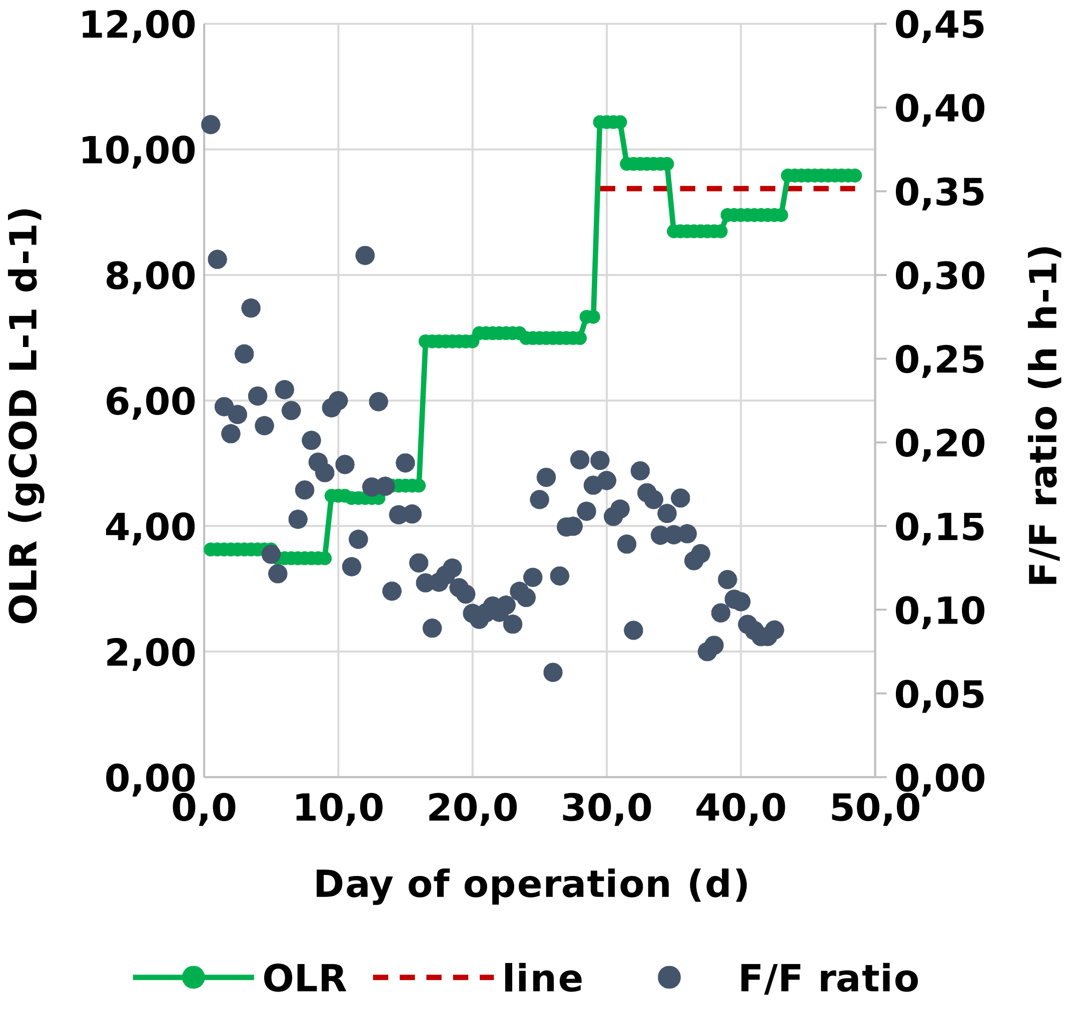
	Lactate	Acetate	Propionate	Ethanol	Butyrate	Iso-Valerate	Valerate	Caproate	Hexanoate	Octanoate	Total
[FP] (gCOD L^{-1})	0	4.8	3.1	0.3	5.8	0.8	2.9	6.1	2.2	0	25.9
% FP	0	18	12	1	22	3	11	24	8	0	100 %

SBR operation

01 OLR up to around 9.3 gCOD L^{-1} d^{-1} was achieved;

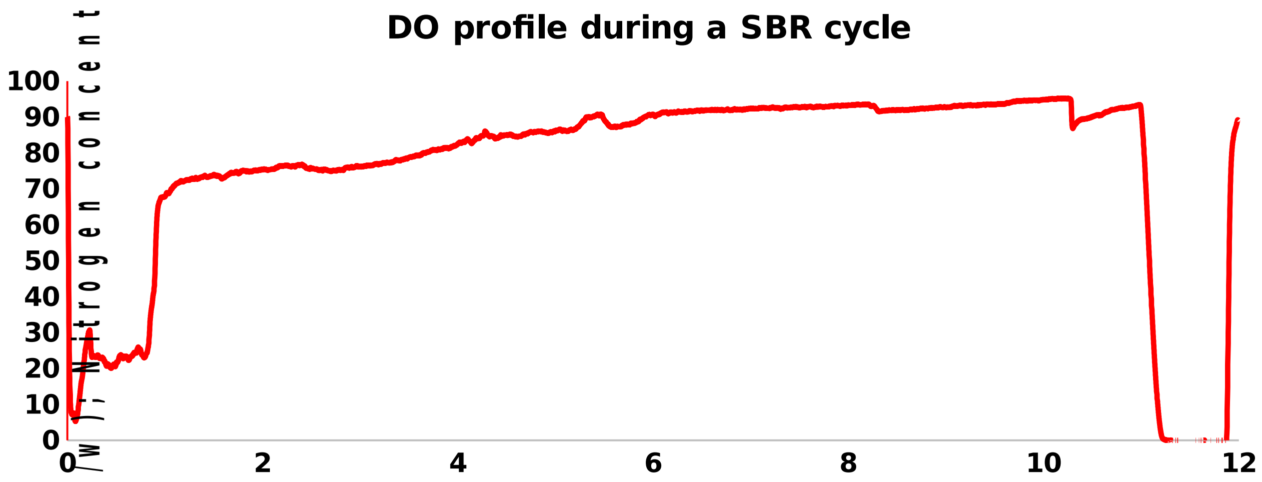
02 F/F ratios as low as 0.1 h h^{-1} can be achieved, hence SBR stability accomplished;

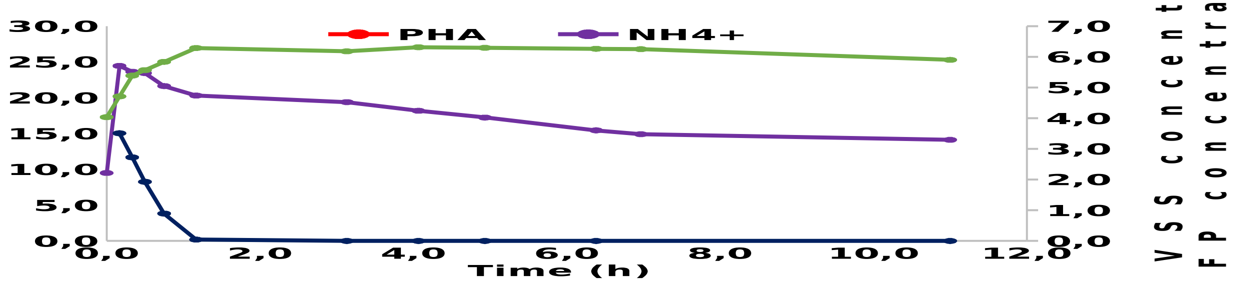
03 Owing to the variability of the FP concentration in the food waste, OLR fluctuated. That variation didn't seem to affect the reactor negatively.



SBR operation

	Phase #1	Phase #2
OLR (gCOD L^{-1} d^{-1})	7.06 ± 0.12	9.42 ± 0.29
Feast/Famine (h h^{-1})	0.11 ± 0.01	0.10 ± 0.03
r_{FP} (gCOD L^{-1} h^{-1})	2.78 ± 0.73	4.08 ± 1.15
r_N (Nmmol L^{-1} h^{-1})	1.67 ± 0.52	2.32 ± 0.81
r_{PHA} (g L^{-1} h^{-1})	1.18	1.93
Maximum PHA concentration (g L^{-1})	2.70	2.95
PHA content at feast phase (gPHA gTS^{-1})	24.9	27.4
HV content (gHV $gPHA^{-1}$)	37.0	37.0
[VSS] at feast phase (g L^{-1})	6.49 ± 0.28	10.2 ± 0.49
N removal in the cycle (Nmol $Nmol^{-1}$, %)	50.8 ± 12.4	60.4 ± 10.3
$Y_{P/S}$ (gCOD $gCOD_{FP}^{-1}$)	61.4	69.9
$Y_{X/S}^{FEAST}$ (gCOD $gCOD_{FP}^{-1}$)	21.5 ± 3.5	17.5 ± 13.4
$Y_{X/P}^{FAMINE}$ (gCOD $gCOD_{PHA}^{-1}$)	30.8	38.8



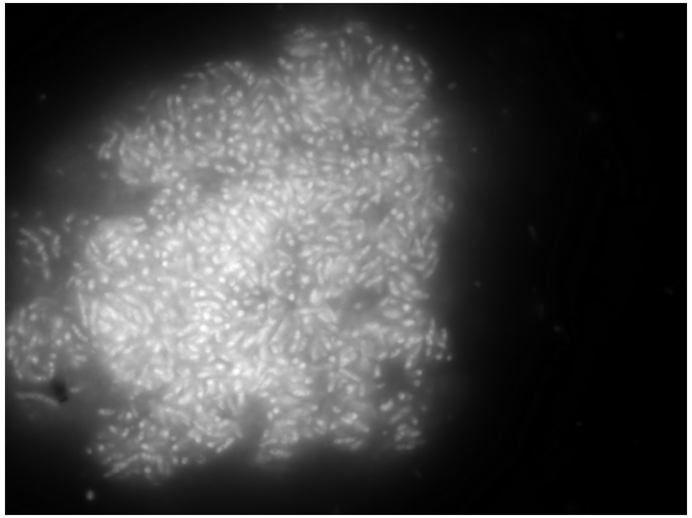


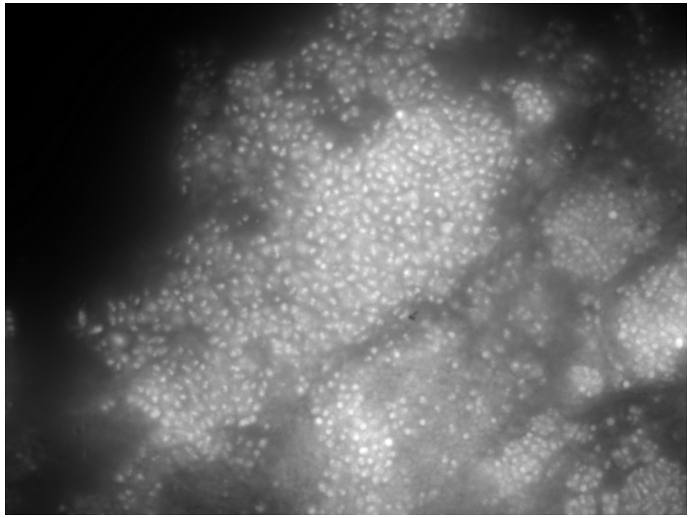
SBR operation

01 PHA data confirmed that selection of PHA-accumulating occurred under these conditions

02 Low COD:N ratio led to ammonia accumulation; However, a rather high VSS concentration was obtained and considerable N removal was achieved

03 No NO_2^- and NO_3^- means no nitrification (no thiourea was fed).

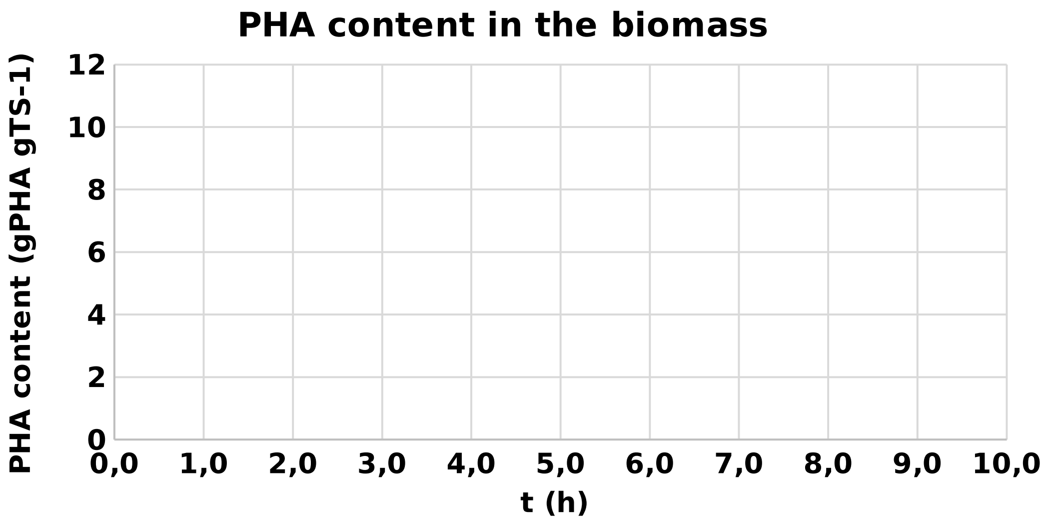


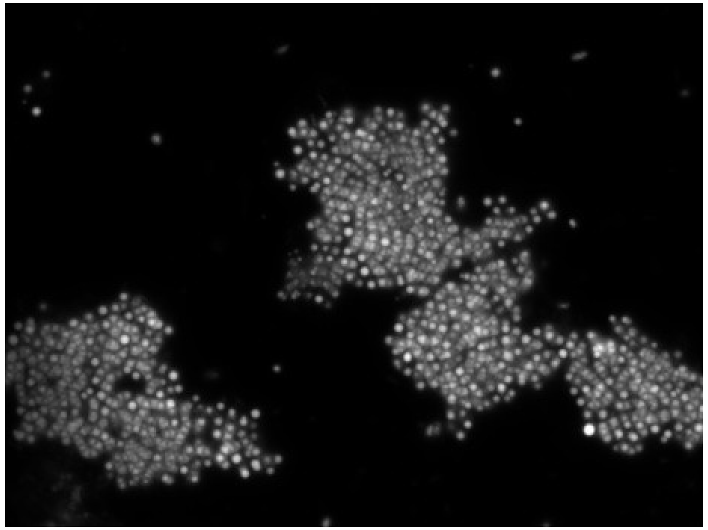


Nile blue staining for PHA granules, day 43

Accumulation reactor operation

	Mean ± SD
PHA content at the end ($gPHA\ gTS^{-1}$)	43.9 ± 3.49
HV content ($gHV\ gPHA^{-1}$)	33.3 ± 1.53
r_{FP}^{AVE} ($gCOD\ L^{-1}\ h^{-1}$)	1.92 ± 0.20
r_{PHA}^{AVE} ($g\ L^{-1}\ h^{-1}$)	0.72 ± 0.17
r_{N}^{AVE} ($Nmmol\ L^{-1}\ h^{-1}$)	3.85 ± 0.47
PHA concentration at the end ($g\ L^{-1}$)	5.62 ± 0.32
Storage yield ($gCOD_{PHA}\ gCOD_{FP}^{-1}$)	0.56 ± 0.07
Storage yield ($gCOD_{PHA}\ COD_{SOL}^{-1}$)	0.45 ± 0.06
Storage yield ($gCOD_{XA}\ gCOD_{SOL}^{-1}$)	0.37 ± 0.06
Global Productivity ($g\ L^{-1}\ h^{-1}$)	0.61 ± 0.09





Nile blue staining for PHA granules, day 28

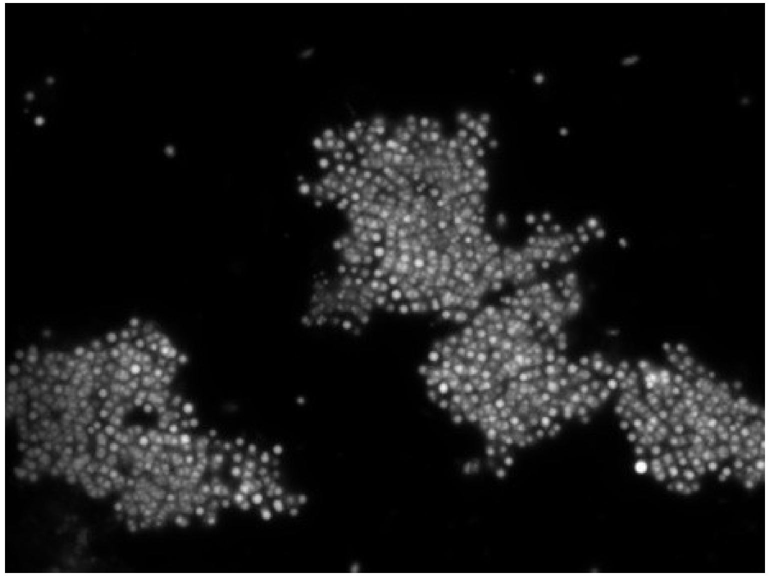
Accumulation reactor operation

01 PHA content above 40 gPHA gTS^{-1} in all assays

02 Butyrate and Valerate were preferable than longer chain FP; medium-chain FP were preferred to acetate and propionate

03 Nitrogen uptake increased along accumulation assay

04 Some residual glucose was consumed along with FP at the beginning of the pulse



Nile blue staining for PHA granules, day 28

33 % HV content
$M_W = 5.48 \times 10^5$
$M_N = 2.67 \times 10^5$
PDI = 2.05

Conclusions and future perspectives

01 The SBR was stable for the period of operation, thus allowing the selection of PHA-accumulating culture

02 Despite the fact that the fermented food waste was rich in ammonia, the selection occurred at a high OLR regardless.

03 PHA content was high enough to be considered economically viable for the PHA-rich biomass be extracted.

04 Demonstration at pilot scale for a longer period of operation that it is technically feasible to produce PHA using this feedstock

05 Owing to the variability of this feedstock, potentially variable parameters (COD/N ratio, unfermented glucose/proteins, variable FP profile, etc…) should be studied on their impact on the stability of the SBR in the long-term

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