



The conversion of food waste and biological sludge into bio-based products: a pilot scale platform for urban waste management

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Circular economy: from waste to resource



New Circular Economy Action Plan 2020 (EC)

- New focus on **product design phase**



- 2.5 billion tonnes of waste generated each year in EU (EPRS, 2016)
- **Problematic disposal for most of categories** (esp. Sewage sludge and organic fraction of municipal solid waste in urban areas)
- Waste framework directive 2008/98/EC (old)
- Few technologies to recover resources applied as **isolated systems**

Biorefineries: transforming treatment plants into resource recovery facilities



URBAN CONTEXT



SOURCE SORTED WASTE
= RENEWABLE SOURCE OF
CARBON



MUNICIPAL WWTP

+ ADDITIONAL TREATMENT
STAGES



VIRGIN MATERIALS FROM
RECOVERED RESOURCES
e.g. Biofuels, biopolymers, etc.



Feed characteristics

OFMSW* (30-35% v/v) - SS mixture (65-70% v/v)



* Slurry after OFMSW squeezing

Parameter	Unit	Jan-Jun 2018
TS	gTS/kg	60 ± 5
TVS	gTVS/kg	49 ± 4
pH	-	4.9 ± 0.3
COD _{VFA}	gCOD/L	2.8 ± 0.5
COD_{SOL}	gCOD/L	22.8 ± 0.4
TKN	gN/kgTS	29 ± 3
Phosphorus	gP/kgTS	2.5 ± 0.6
N-NH ₄ ⁺	g/L	0.31 ± 0.02
P-PO ₄ ³⁻	g/L	0.20 ± 0.01
COD_{SOL}:N:P	g	100 : 7.4 : 1.5

Treviso (TV) WWTP ATS S.r.l.

(Alto Trevigiano Servizi – North East Italy)

OFMSW-Sludge Anaerobic Co-digestion

Feed characteristics

Flow, m ³ /d	10 biowaste + 100 sludge
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TVS, %TS	70
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Operational parameters

OLR, kgVS/m ³ d	1.5
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HRT, d	20-24
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Temperature, °C	35-37
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Yields

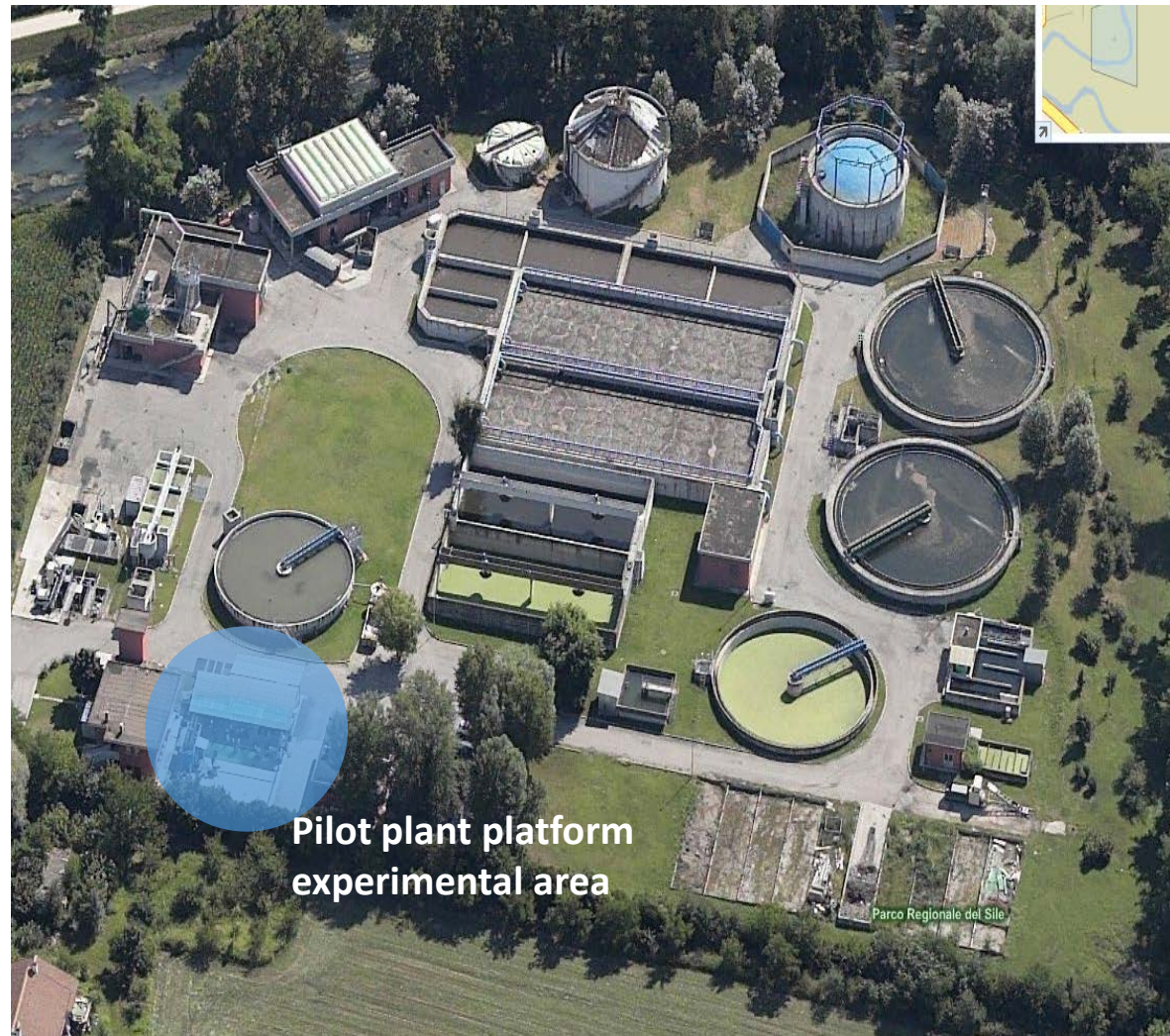
Biogas, Nm ³ /d	950
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Methane, %	60-66
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SGP, Nm ³ /kg VS (% biowaste)	0.43
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TS removal, %	28
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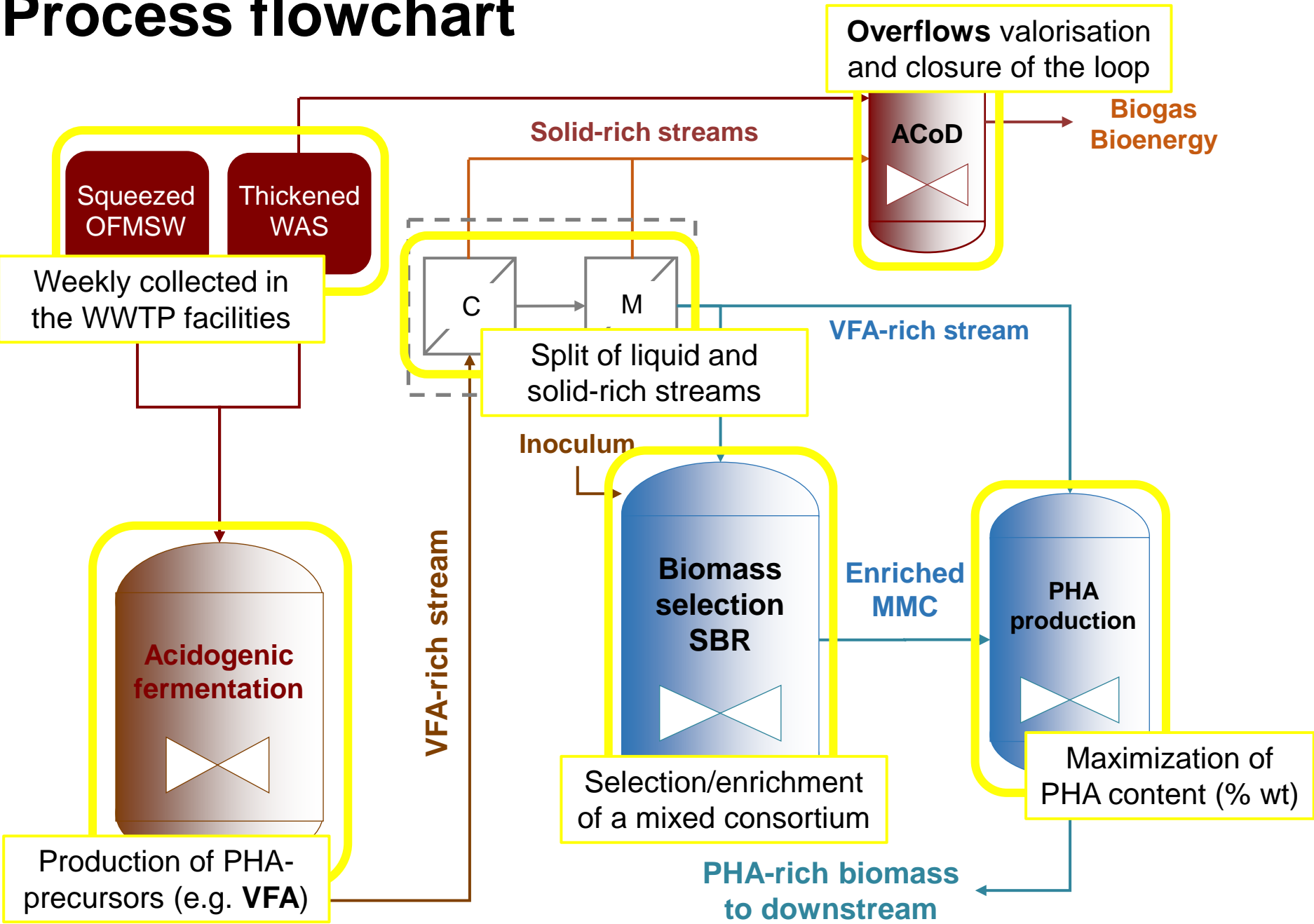
VS removal, %	39
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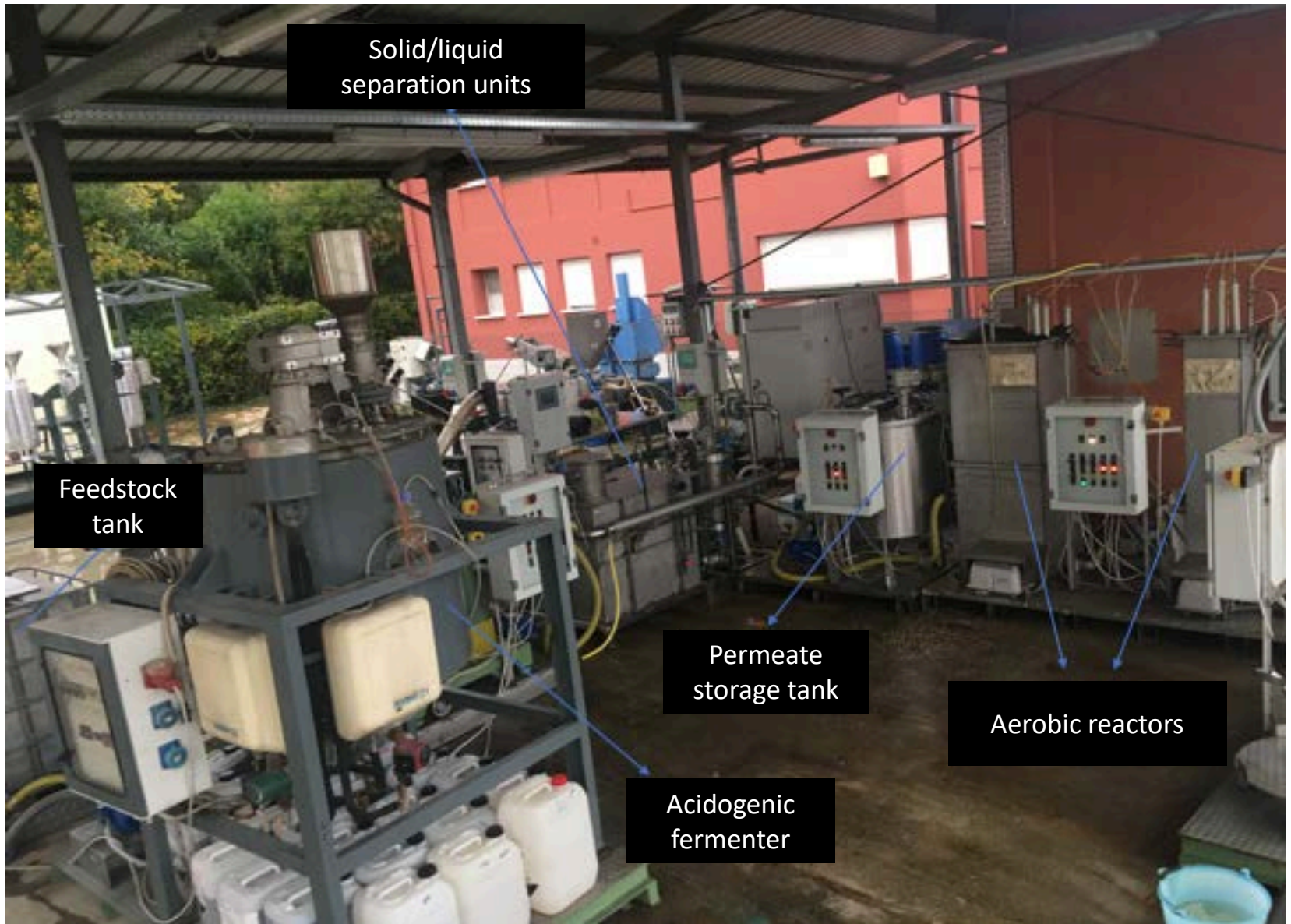
Pilot plant platform
experimental area

Parco Regionale del Sile

Process flowchart



Pilot Plant Biorefinery for PHA production



Acidogenic fermentation

Fermenter operating conditions

**Feedstock: OFMSW-WAS
(30-40% - 70-60% v/v)**

Working Volume = 380 L

Thermal pre-treatment
70°C, 48 h

CSTR

HRT = 6 days

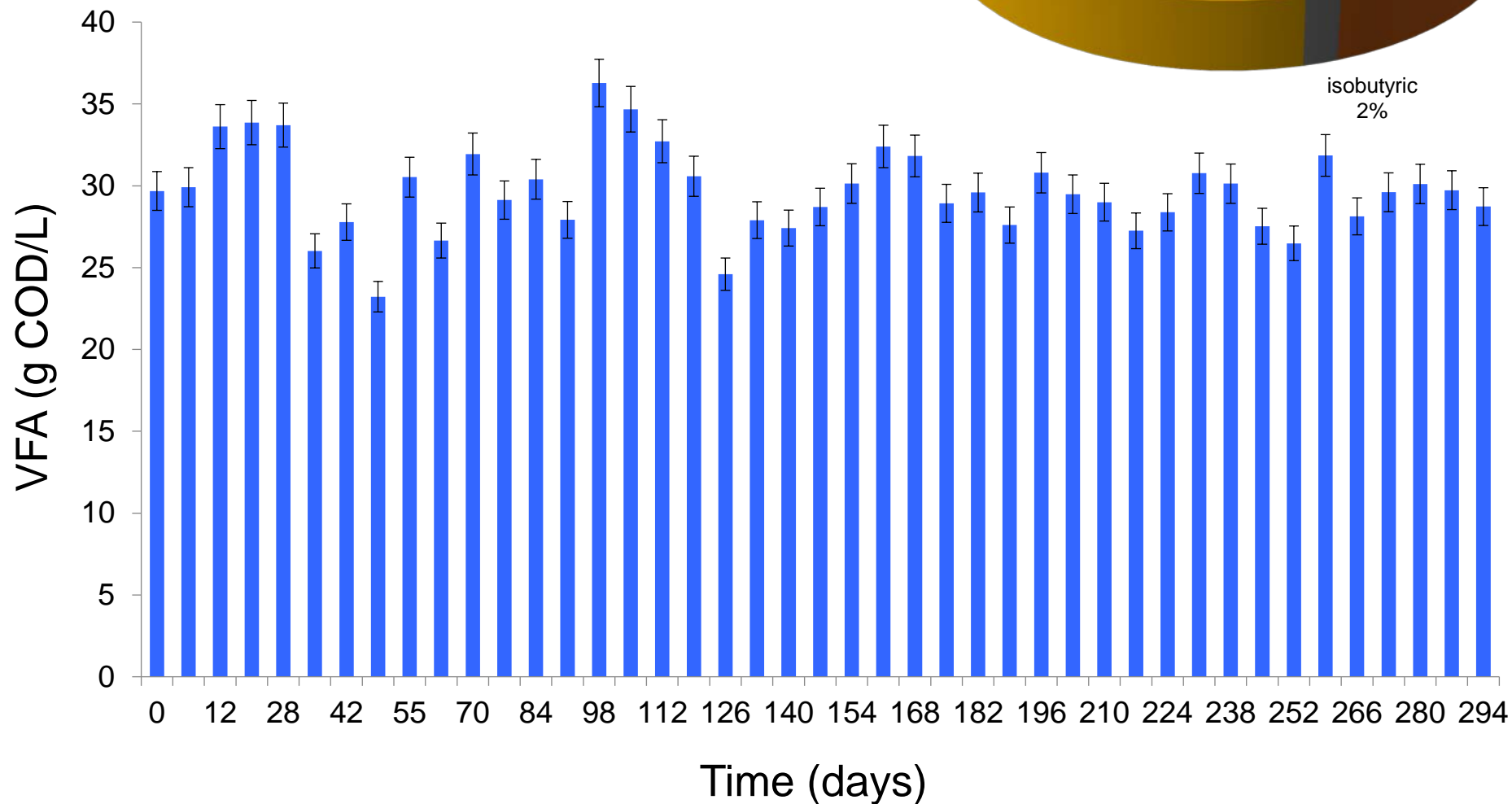
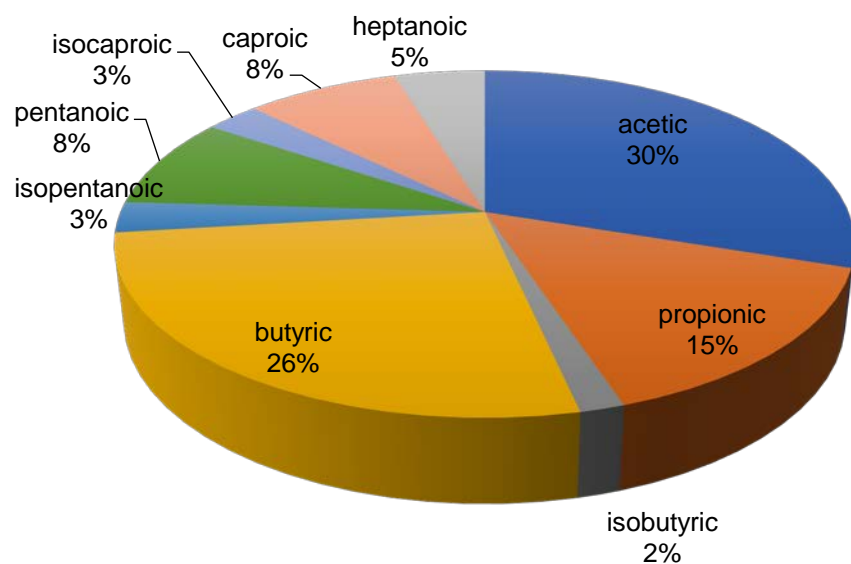
T = 37°C

pH = uncontrolled

Best performances

(heat pretr. + mesophilic fermentation)

- VFA = 30.1 ± 0.4 g COD/L
- VFA/COD_{SOL} = **0.86** \pm 0.05
- COD_{VFA} : N : P = 100 : 3.3 : 0.9



OVERFLOWS - Suitable for anaerobic codigestion after dilution with WAS

Acidogenic fermentation effluent



VFA-rich liquid stream

Solid-rich stream (23% TS)

+ WAS

Anaerobic co-digestion

Solid stream (2% TS)

VFA-rich liquid stream

PHA aerobic line



Anaerobic co-digestion (AcoD)

Operating conditions

Feedstock mixture

- 1) Thickened WAS
- 2) Centrifuge solid fraction (cake)
- 3) Membrane retained phase

Working Volume = 230 L

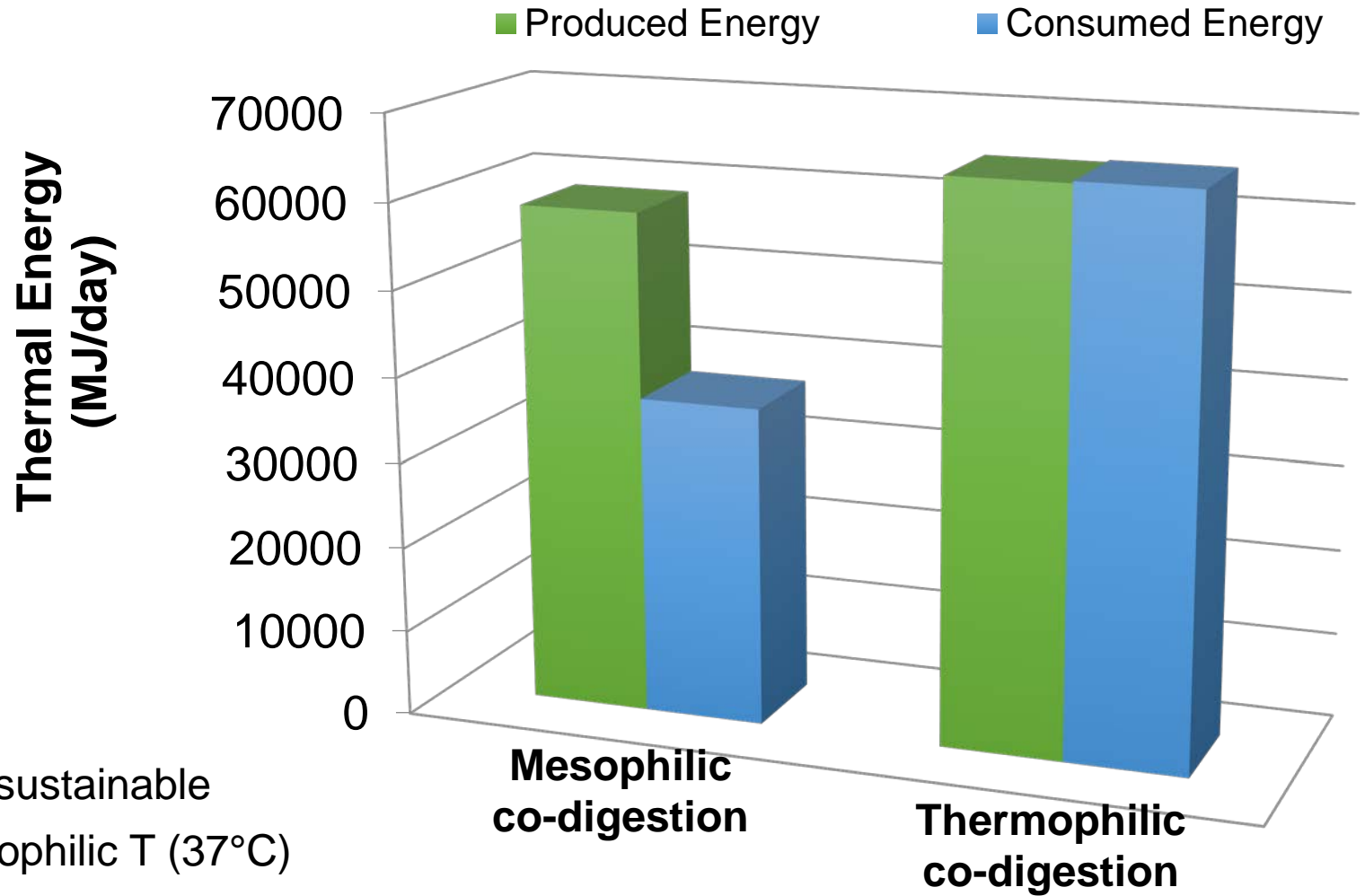
CSTR

HRT = 15-20 d

OLR = 2.0-3.5 kg VS/m³d

T = 37°C - 55°C

Energy Balance



- Thermally sustainable under mesophilic T (37°C)
- SGP = 0.44 m³/kg VS

Aerobic PHA line

Sequencing Batch Reactor (SBR) + fed-batch accumulation reactor

Working Volume = 120 L

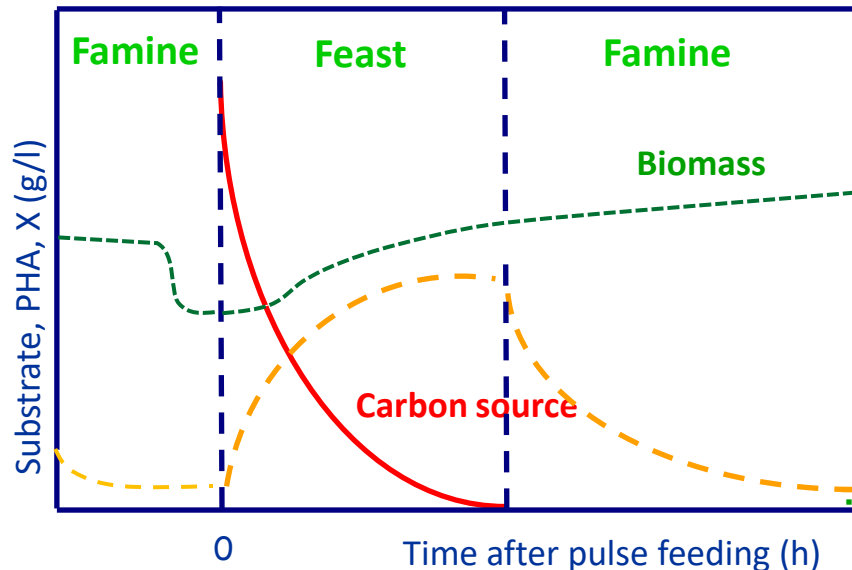
SBR (biomass production)

HRT = SRT = 2 d

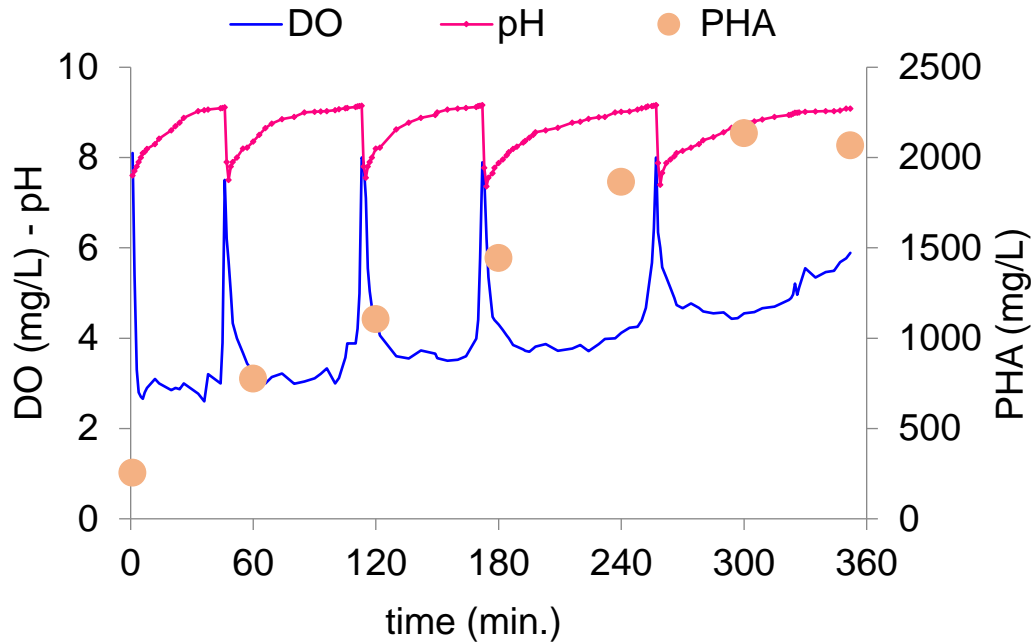
Cycle length = 12 h

OLR = 4.0 kg COD_{SOL}/m³ d

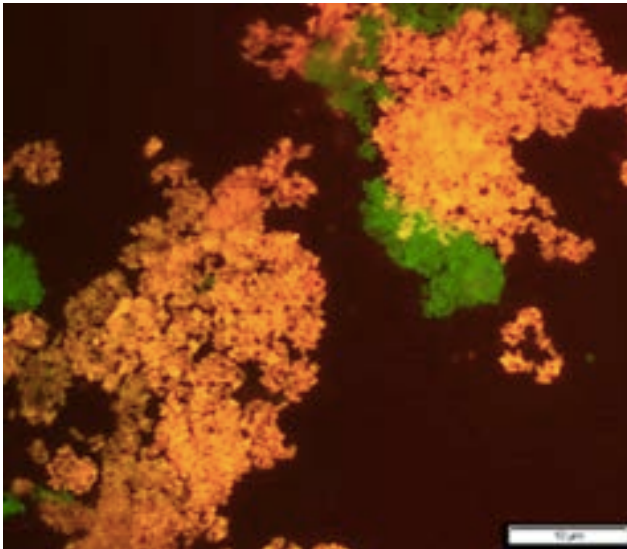
T = 25°C - 28°C



PHA accumulation and microbial community



Fed-batch accumulation reactor	
Parameter	Values
Maximum PHA content (g PHA/g VSS)	0.42 - 0.62
Storage Yield (g PHA/g VFA) _{COD}	0.49 - 0.52
PHA composition (g HB/g HV)	(80-91)/(9-20)



FISH image

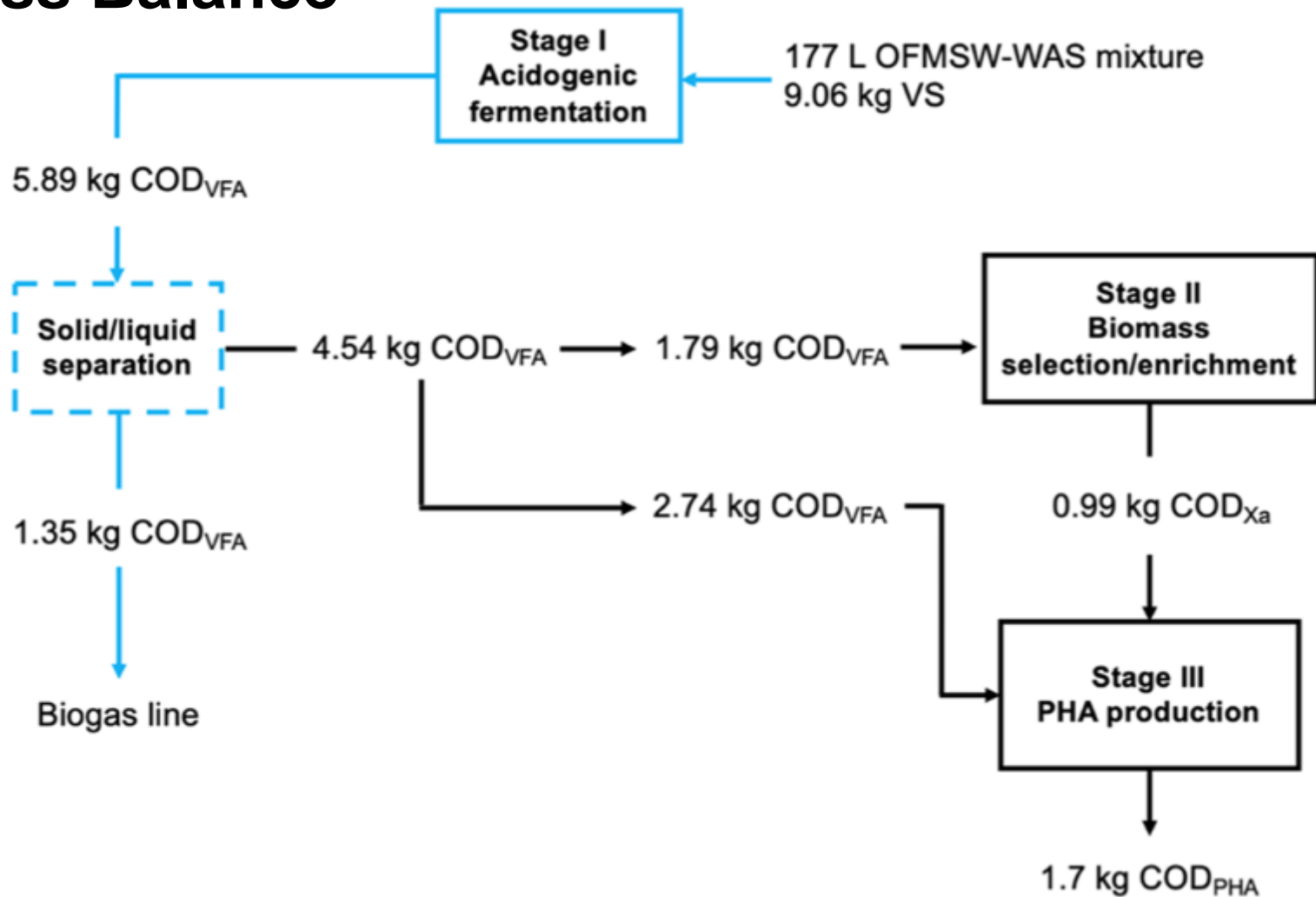
green: Bacteria (EUB mix probe)

orange: *Hydrogenophaga* cells (HYD208 probe)

80% of total bacteria

Scale bar = 10 μ m

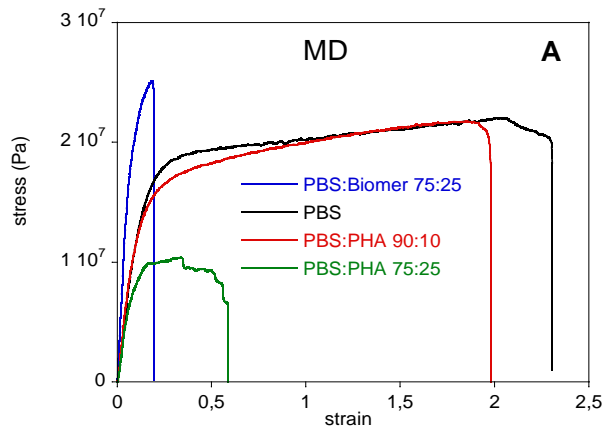
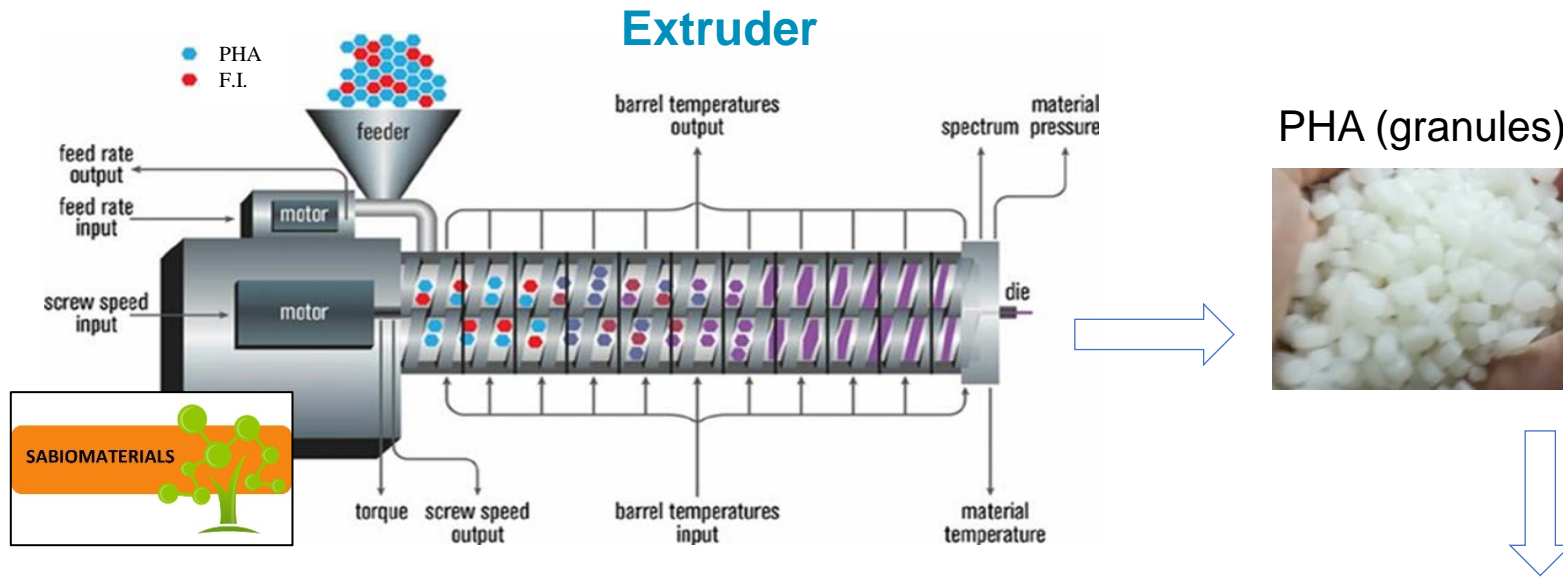
Mass Balance



- $Y_{Xa/VFA}^{SBR} = 0.55 \text{ COD}_{Xa}/\text{COD}_{VFA}$
- $Y_{P/VFA}^{\text{batch}} = 0.61 \text{ COD}_{PHA}/\text{COD}_{VFA}$
- 30% v/v reduction in the S/L separation stage

• **11% OVERALL YIELD
kg PHA/kg VS**

Main achievements (1)



Mechanical tests



Film



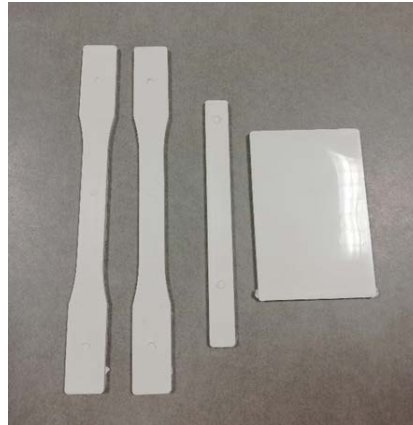
Blow molding

Main achievements (2)

PHA compound in pellet (>90% PHA)



Prototypes for mechanical tests

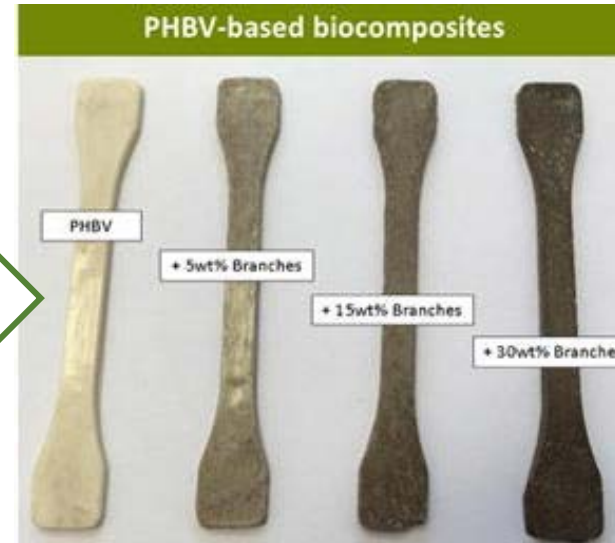


Flexible handle



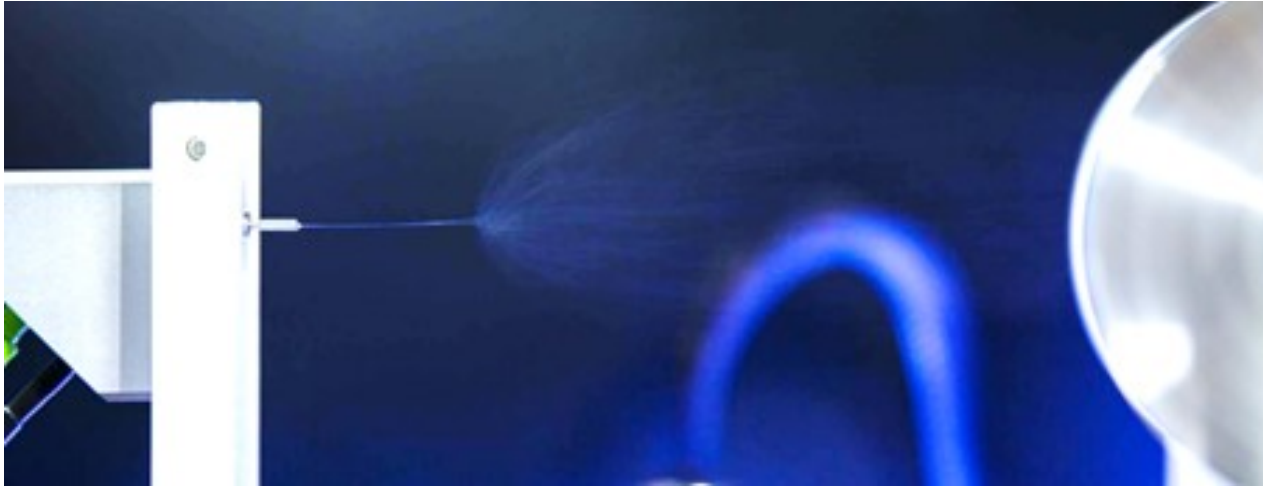
PHBV compounds with fibers collected from green biowastes

Viretto et al. Waste Management
<https://doi.org/10.1016/j.wasman.2020.10.018>

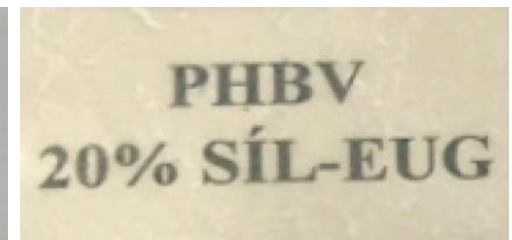
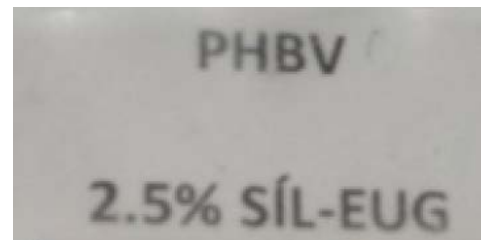
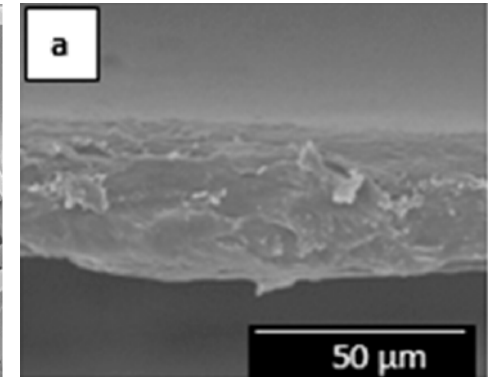
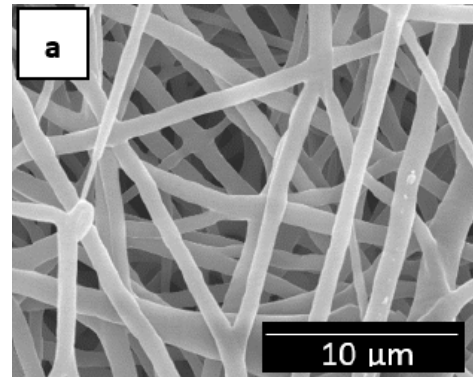


Main achievements (3)

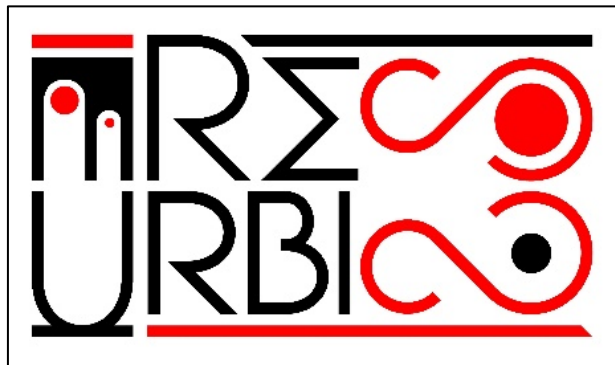
Electrospinning



- Multi-layers film for permeability assessment
- Nanoparticles incorporation for properties improvement (active packaging, es. antimicrobial)
- Application as adhesive in substitution of fossil-origin products



Many thanks for your attention



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