University of Verona, Department of Biotechnology

Volatile fatty acids production from organic waste for biorefinery platforms

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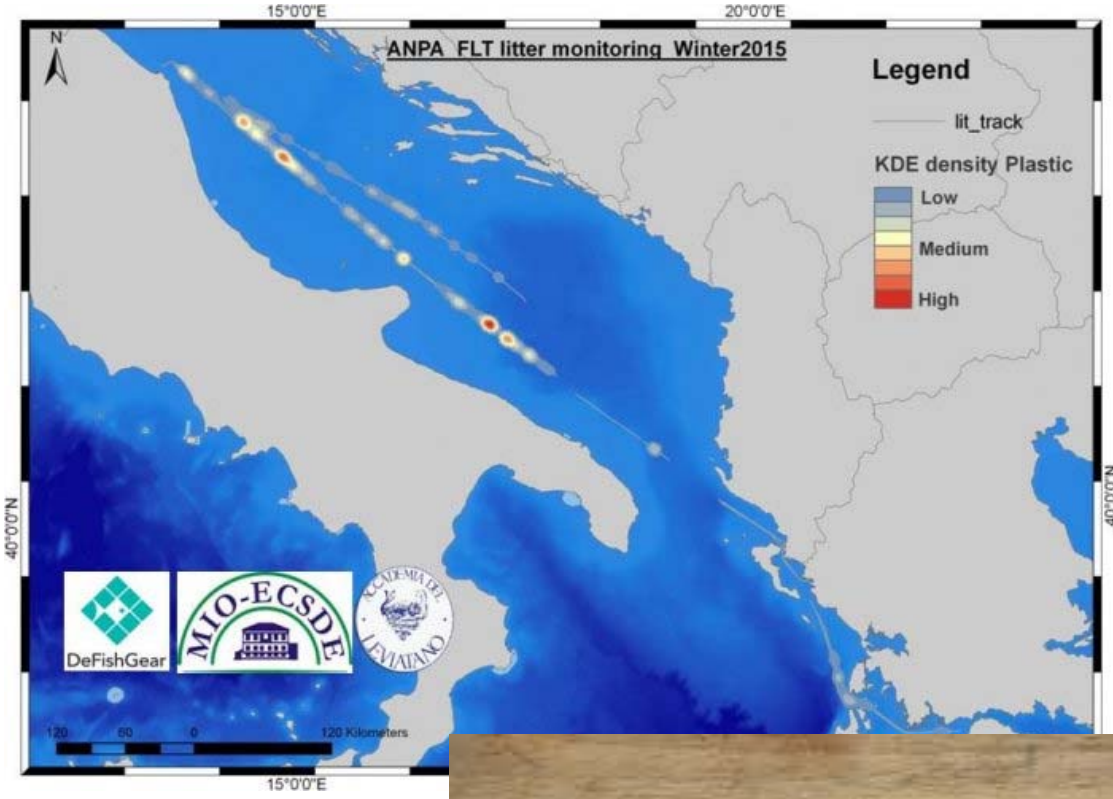
Being un-biodegradable, once wasted, if not recycled, it accumulates in the environment

The plastic islands forming the «plastic continent»

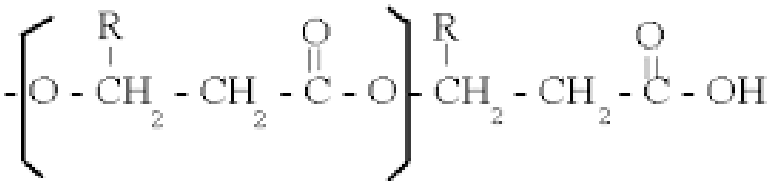
Marine litter: microplastics along the sea food chain



We need for a new generation of bio-plastics:

3 times BIO

- Originated fom **bio**-mass
- Through a **bio**-process
- and is **bio-**degradable



Poly (3-hydroxyalkanoate) (PHA)

R = CH3, Poly(3 hydroxybutyrate)
R = CH2-CH3, Poly(3-hydroxyvalerate)

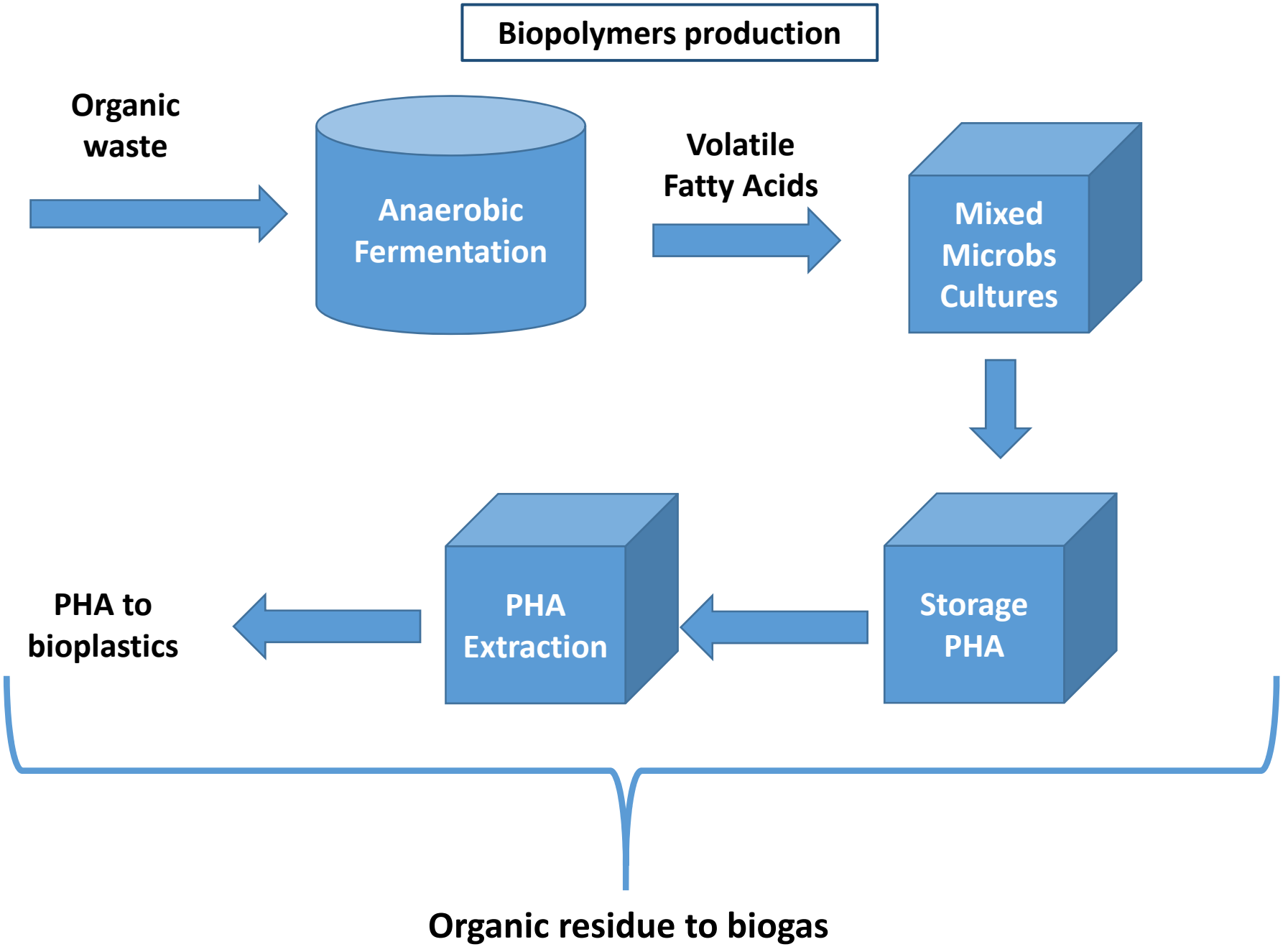
Organic waste

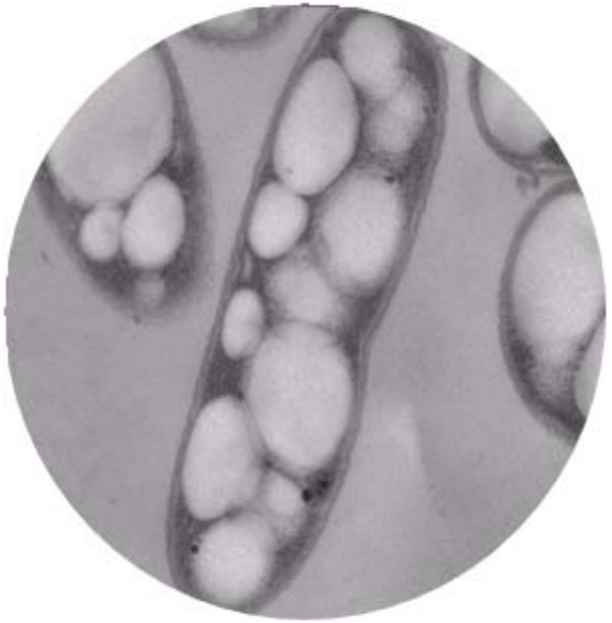


Volatile Fatty Acids

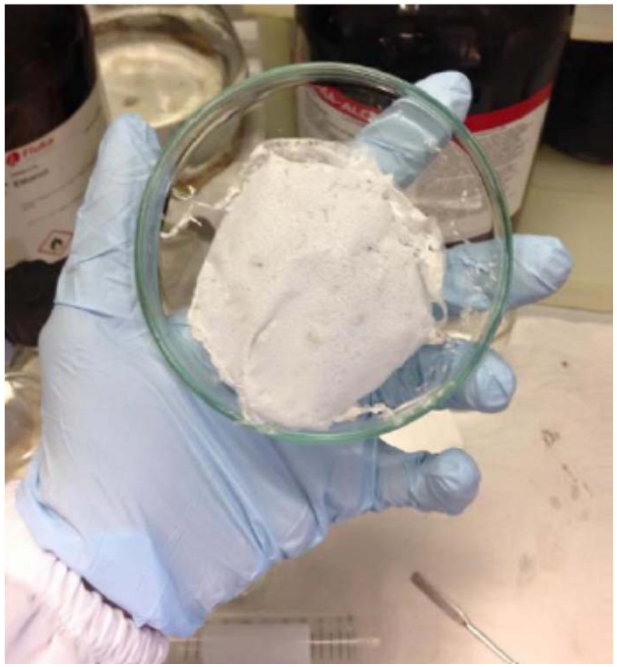
Biopolymers

Bioplastics


Biopolymers production
Organic waste
Anaerobic Fermentation
Volatile Fatty Acids
Mixed Microbs Cultures
Storage PHA
PHA Extraction
PHA to bioplastics
Organic residue to biogas



PHA stored in cells



PHA extracted from a mixed microbial culture

Fermentation of organic waste to volatile fatty acids

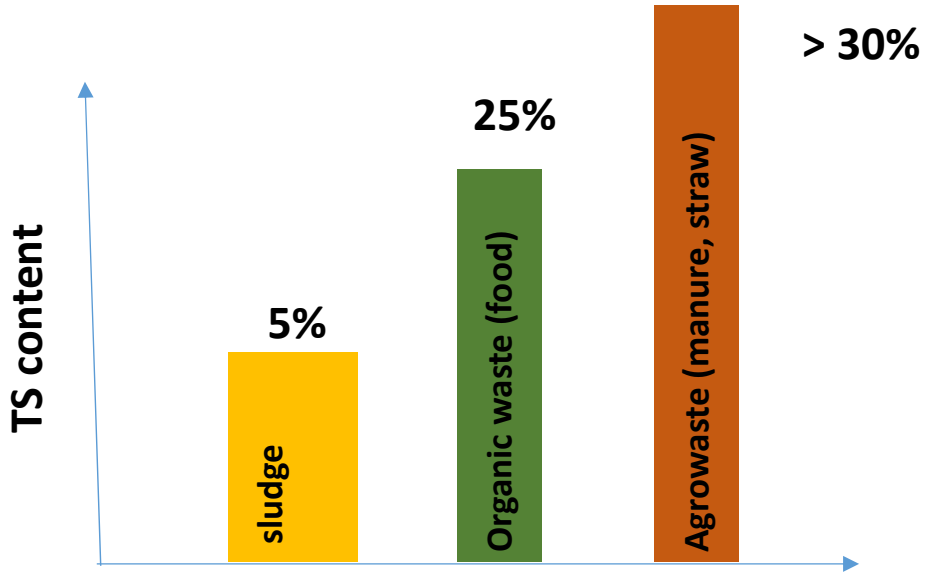
Feedstock

- **Organic Fraction of Municipal Solid Waste, (OFMSW);**
  (household food waste, residues from markets, restaurants, canteens, cafeterias, etc.).
- **Wastewater Sludge;**
- **Agro-waste and Livestock Effluents.**

Characterisation of the organic waste used for VFAs production

Origin of waste	Type of waste	TS g·kg^{-1}	TVS g·kg^{-1}	TVS/TS %	COD g·kg^{-1}	TN g·kg^{-1}	TP g·kg^{-1}	References
OFMSW	SS-OFMSW	288	228	80	347	28	2.4	(Bolzonella et al. 2005)
	SC-OFMSW	88	80	91	102	23	3.7	(Traverso et al. 2000)
	MS-OFMSW	647	301	45	510	14	14	(Sans et al 1995)
	Food waste	260	216	83	954	7.5	0.8	(Micolucci et al. 2014)
AGROWASTE and LIVESTOCK EFFLUENT	Wheat straw	940	871	92.7	1081	N.A	N.A.	(Sambusiti et al 2013)
	Ensiled Sorgum Forage	930	805	86.6	1125	N.A	N.A.	(Sambusiti et al 2013)
	Maize silage	333	313	94	996	14.2	3.1	(Cavinato et al. 2017)
	Cow manure	207	169	82	882	27.8	4.7	(Cavinato et al. 2017)
SLUDGE	Waste activated sludge	37	30	79	33	1.8	0.5	(Bolzonella et al. 2007)
	Waste activated sludge	62	43	68	48	3.1	0.9	(Leite et al. 2016)
	Sewage sludge (primary and secondary)	19	15.6	81	18	0.8	0.3	(Longo et al. 2015)

**N.A.= not available*



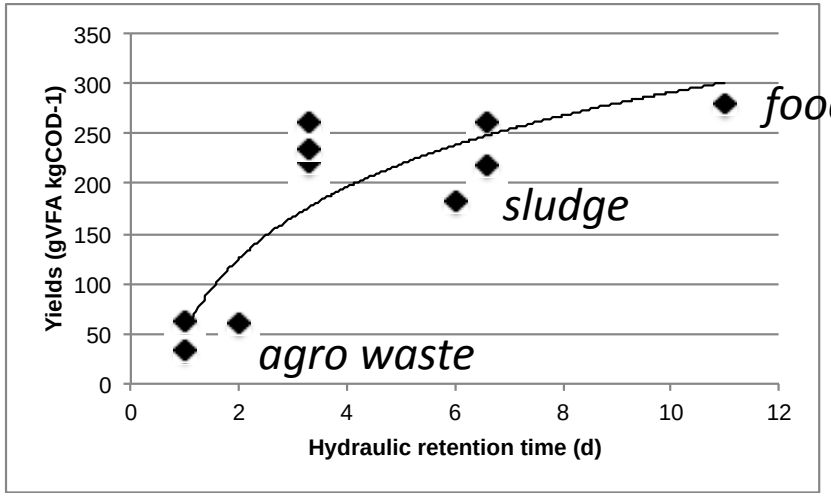
Reactors operational conditions

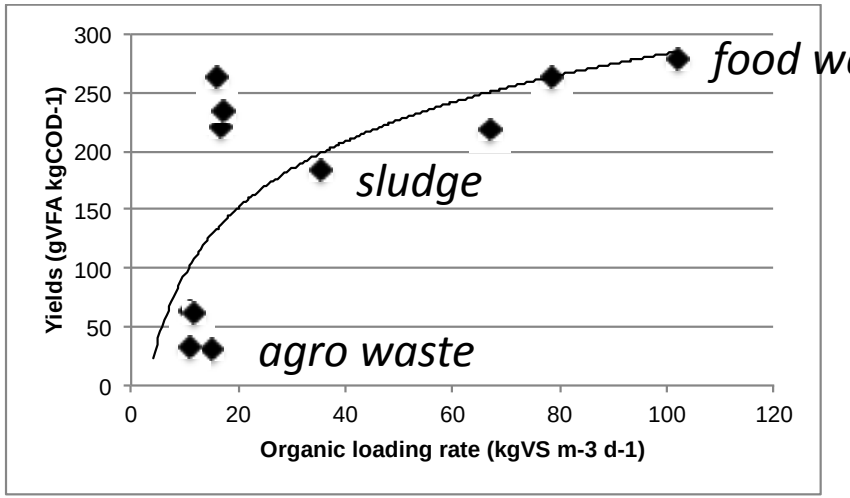
- **Feeding system:**
  - Semi-continuous approach;
- **Temperature :**
  - psychrophilic (**23 °C**), mesophilic (**35-37 °C**) and thermophilic (**55 °C**);
- **OLR:**
  - OFMSW and Food Waste: from **4** to **102** kgVS $m^{-3}d^{-1}$;
  - Waste Activated Sludge: from **1.2** to **28.9** kgVS $m^{-3}d^{-1}$;
  - Agrowaste: : from **12** to **35** kgVS $m^{-3}d^{-1}$
- **HRT:**
  - from **1** to **6** d.

Volatile Fatty Acids yields and composition

Feedstock	HRT, (d)	OLR, (kgVS·m^{-3}·d^{-1})	Temperature (°C)	Yield, gVFA·kgCOD^{-1}	Conc. VFA (g·L^{-1})	References
OFMSW	6	4.1	23	127	9.5	(Cecchi et al., 1994)
OFMSW	1-6.6	11-66.9	35-37	64-218	7.9-23.1	(Cecchi et al., 1994; Pavan et al., 1998; Sans et al., 1995)
OFMSW	3.5	16	55	263	13.8	(Cavinato et al, 2011)
OFMSW	6.6	21	55	60	8.3	(Cavinato et al., 2011)
OFMSW	1-6.6	15-78.5	55	31-263	2.5-19.6	(Cavinato et al., 2012, 2011; Chinellato et al., 2013; Sans et al., 1995)
Food Waste	3.0-3.3	16.8-17	55-55	221-234	12.3-13.7	(Micolucci et al, 2014) (Giuliano et al., 2014)
Food Waste & Rice Straw	8	4-42.95 (gVS·L^{-1}d^{-1})	35	N.A.	~ 5.5-25.0	(Chen et al., 2015)
Synthetic Food Waste	5	5-6 (gTS·L^{-1})	35	N.A.	13.27-24.93	(Jiang et al., 2013)
Fruit/Vegetable waste	1-11	11-102	37	33-279	7.6-28.5	(Traverso et al., 2000)
Fruit/Vegetable waste	5	4.8 (gVS·L^{-1}d^{-1})	35	N.A.	~ 15	(Zheng et al., 2015)
WAS	4.6-5.9	1.2-1.9	35	207-325	3.2-7.5	(Longo et al., 2015)*
	2	15	55	383	11.4	(Leite et al., 2016)
	1-5	6.5-28.9	70	220-277	6.5-9.0	(Bolzonella et al., 2007)
OFMSW + WAS	3.3	18	55	137	8.1	(Gottardo et al., 2015)
Wheat straw	3-7	8	55-60	NA	1	(Pohl et al 2013)
Corn straw	3	30 (kgVS/m3)	35	NA	6.77	(Dong et al 2016)
Caw Manure-maize silage	2-6	11.9-35.4	37-55	62-183	6.7-14.6	(Cavinato et al., 2017)

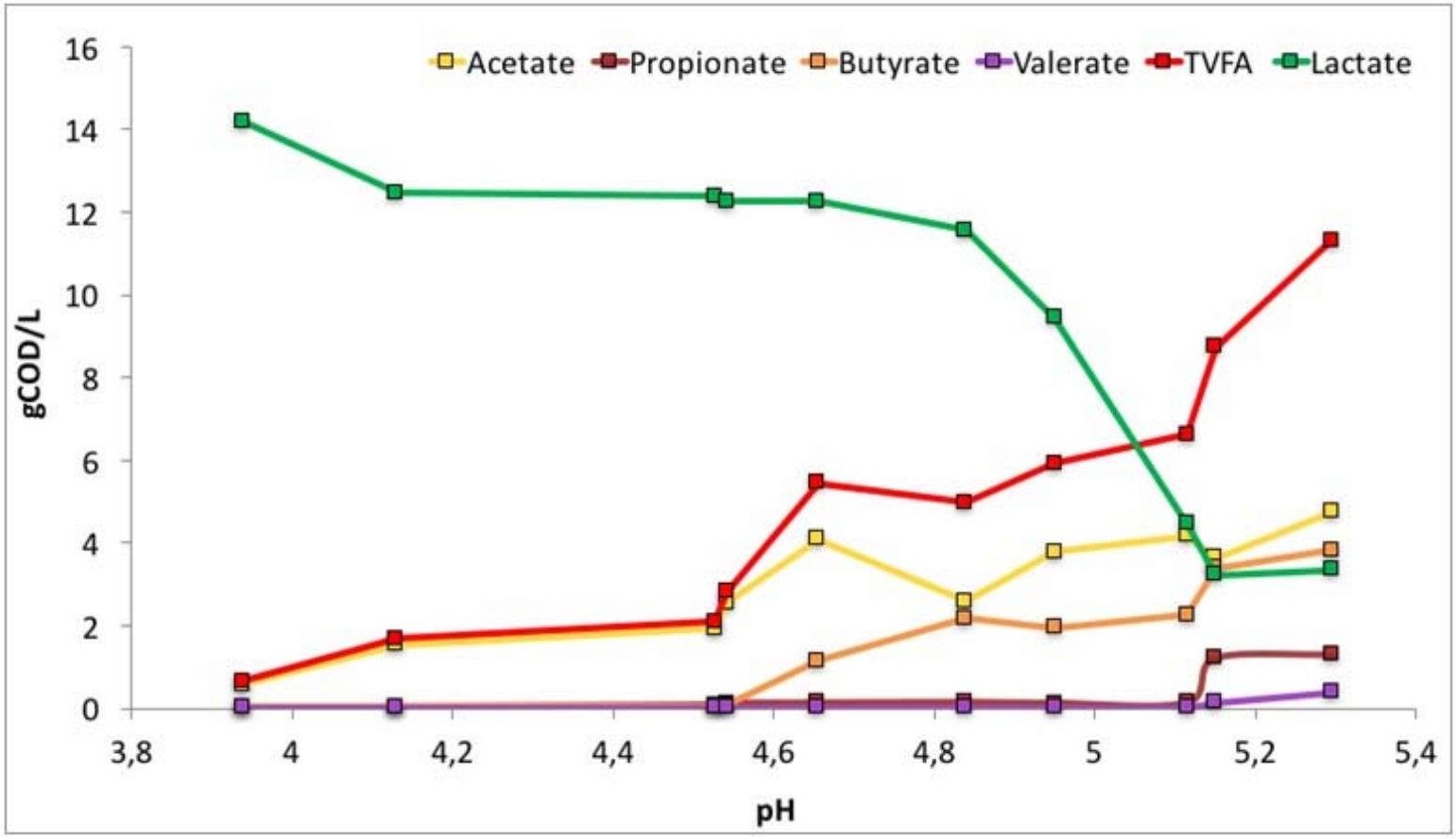
Volatile Fatty Acids yields vs HRT & OLR



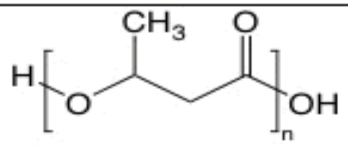
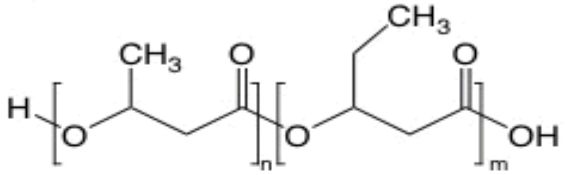
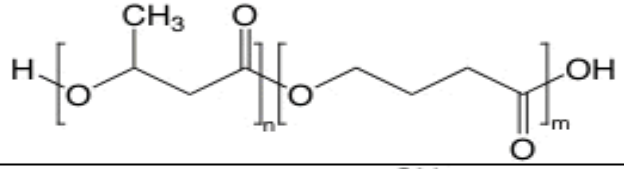
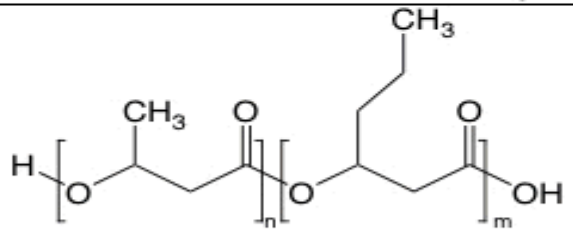
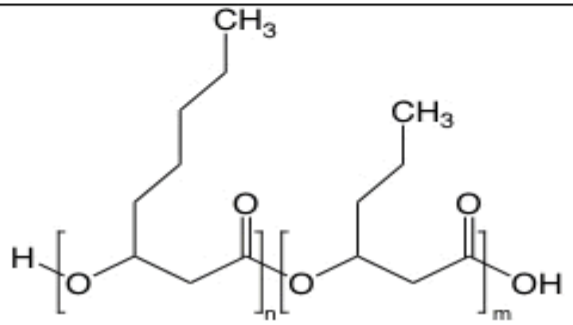


VFAs production from OFMSW, Food waste and Agro waste Vs. Hydraulic retention time / Organic loading rate.

Different organic molecules from food waste fermentation allows for biopolymers tuning !



Different organic molecules from food waste fermentation allows for biopolymers tuning

PHA synthesized	PHA chemical structure
PHB [poly(3-hydroxybutyrate)]	
PHBV [poly(3-hydroxybutyrate-co-3-hydroxyvalerate)]	
P3HB4HB [poly(3-hydroxybutyrate-co-4-hydroxybutyrate)]	
PHBHHx [poly(3-hydroxybutyrate-co-3-hydroxyhexanoate)]	
PHOHHx [poly(3-hydroxyoctanoate-co-3-hydroxyhexanoate)]	

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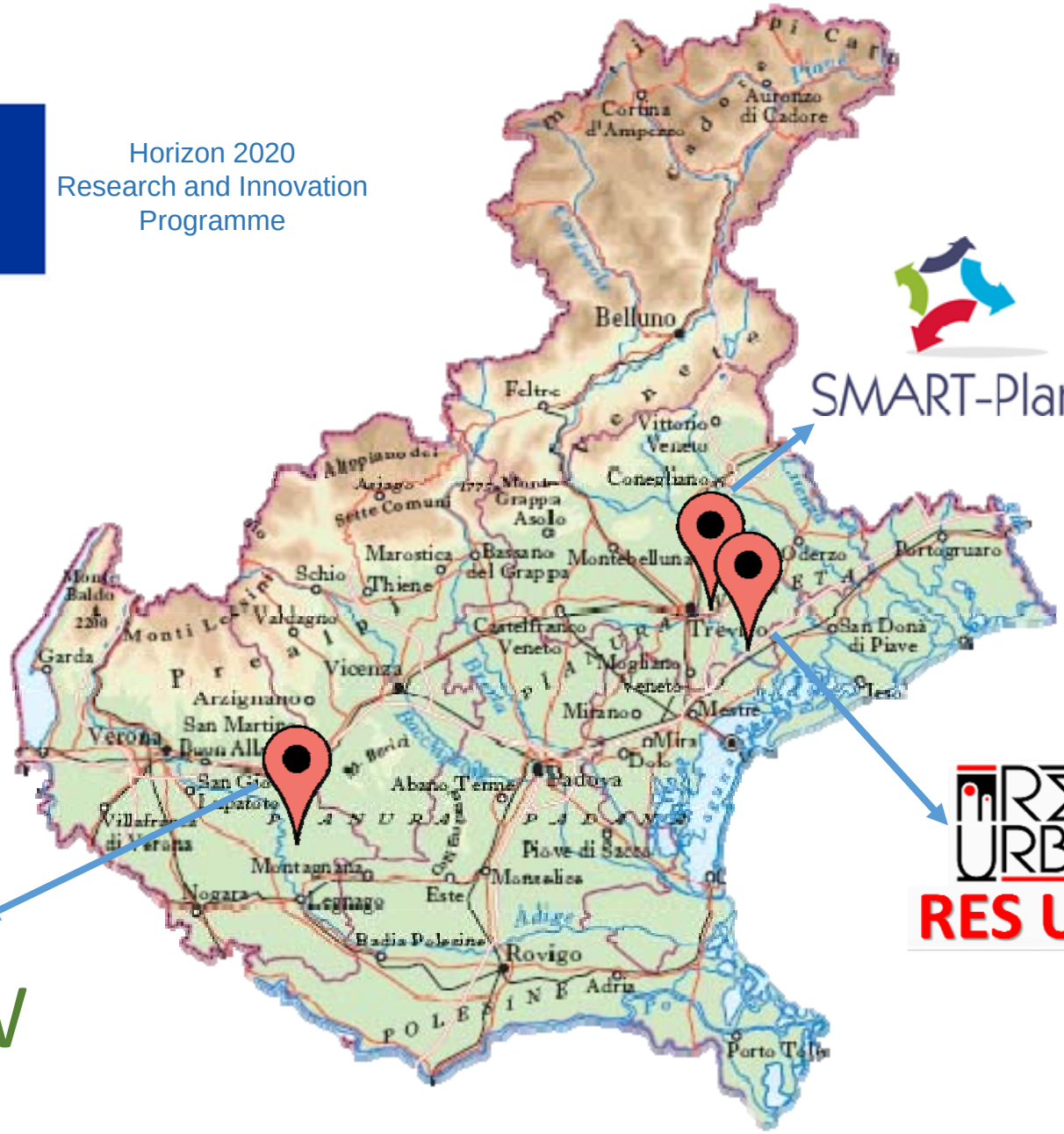

SMART-Plant

RES URBIS

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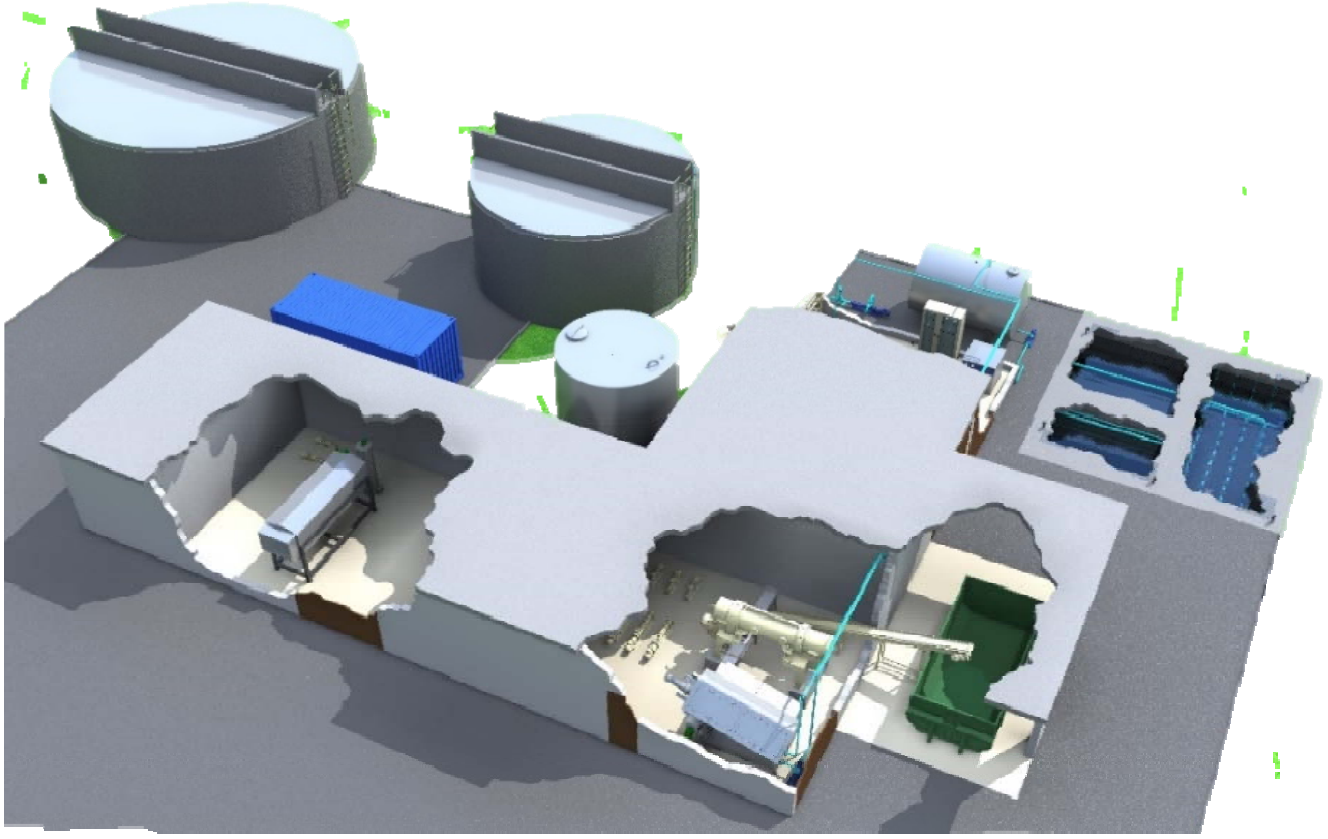

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Pilot plant platform for PHA production

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Hosted at La Torre farm, 30 hectars 6,000 bulls and cows (12,000 total capacity), 2 AD reactors (1MW each)

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Take home messages:

1. **We need to replace oil based plastics with 3 bio – plastics**

2. **We are working at pilot / demo scale to produce considerable amount of biopolymers for material testing and demonstrate the market feasability**

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