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Improvement of VFA production from food waste using biological pretreatments

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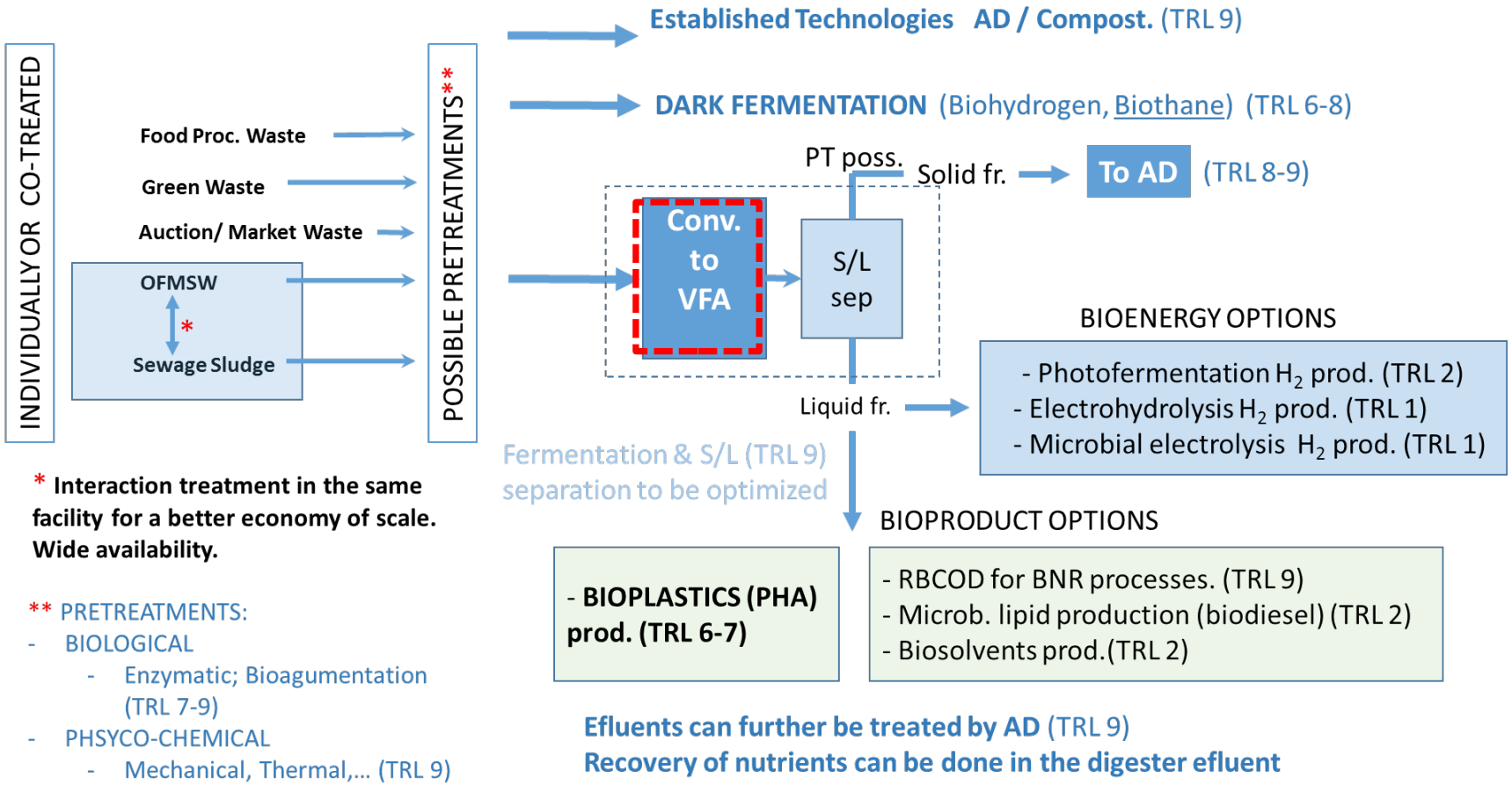
FOOD WASTE TREATMENT (OR CO-TREATMENT) IN THE BIOREFINERY CONTEXT

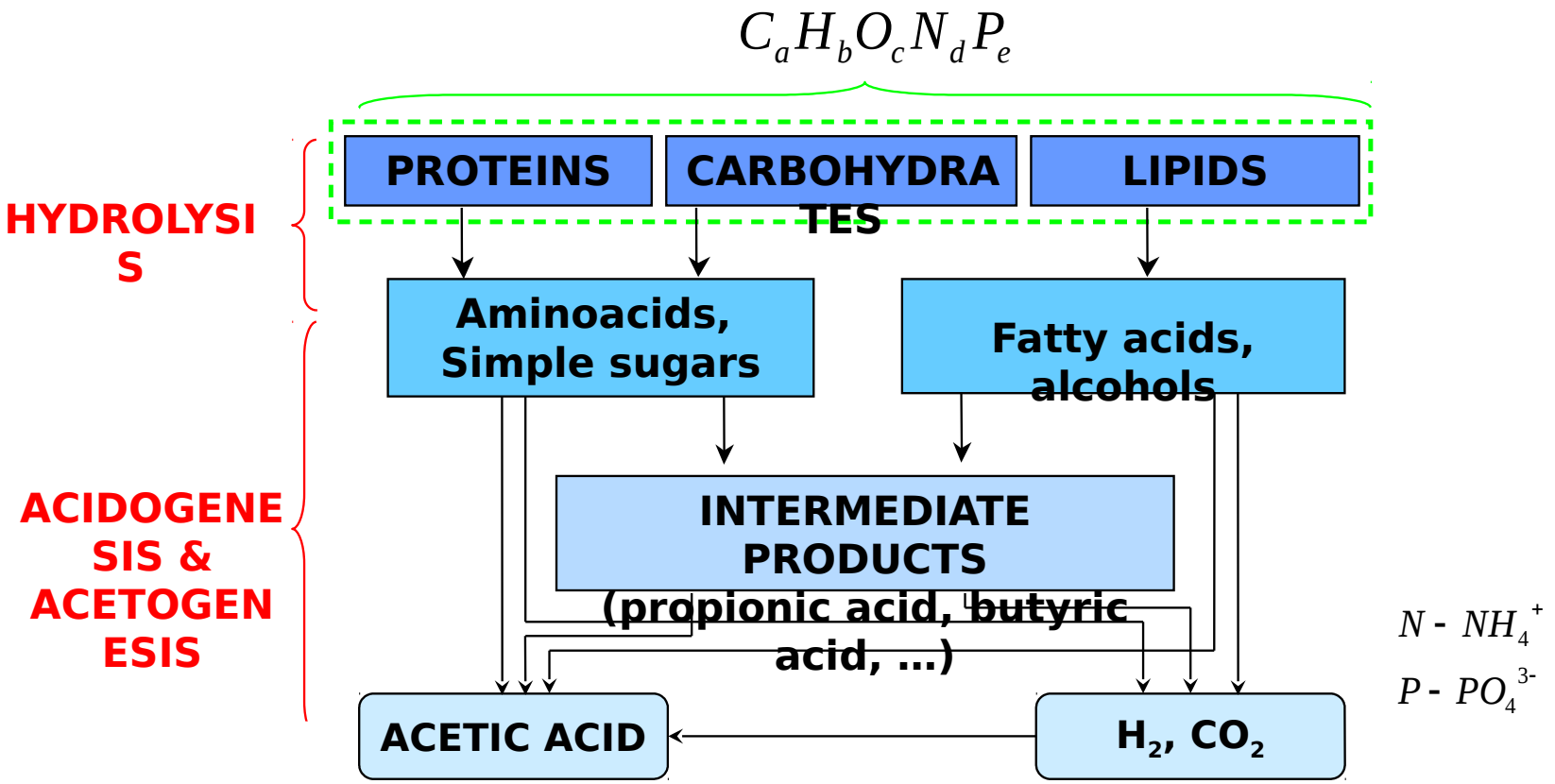


* **Interaction treatment in the same facility for a better economy of scale. Wide availability.**

** PRETREATMENTS:
- BIOLOGICAL
  - Enzymatic; Bioagumentation (TRL 7-9)
- PHSYCO-CHEMICAL
  - Mechanical, Thermal,… (TRL 9)

Efluents can further be treated by AD (TRL 9)
Recovery of nutrients can be done in the digester efluent

ACIDOGENIC FERMENTATION



- Type of substrate and co-substrates fed
- Operational parameters

REGULATION OF

- ✓ **VFA Concentration**
- ✓ **VFA Composition**
- ✓ **Ratio $COD_{VFA}/COD_{SOLUBLE}$**

BIOLOGICAL PRE-TREATMENTS

Hydrolysis is usually the limiting step of acidogenic fermentation.

BIOLOGICAL PRETREATMENTS are getting more attention to improve acidogenic fermentation. since they do not require reagent addition and do not require high energy demands to be applied.

In this study, **2 biological pretreatments** were **studied** to improve hydrolysis and VFA production:

1) ADDITION OF MATURE COMPOST

Mature compost contains a variety of **hydrolytic bacteria** , by adding it into acidogenic fermenter, they will enhance **solubilisation** and hence, increase the rate of **hydrolysis** for **VFA production**.

2) ADDITION OF WASTE ACTIVATED SLUDGE PRETREATED AT 55ºC

Treating **WAS at 55 ºC**, the microorganisms release **extracellular polymeric substances** (EPS) that are contained in their own metabolic system resulting in **autohydrolysis** (Carvajal et al., 2013; Arias et al., 2018).

EXPERIMENTAL DEVICES FOR ACIDOGENIC FERMENTATION

Batch test assays

Effect of mature compost or pretreated WAS addition

Semi-continuous lab-scale reactors (5L)

Operating at 35°C and 3.5/5d of HRT, pH6/7, with and without compost addition

ANALYTICAL METHODS

***Standard Methods for the Examination of Water and Wastewater* (APHA, 2012)**

SUBSTRATE AND INOCULUM

SUBSTRATES	INOCULUM
FOOD WASTE (University Canteen) **WASTE ACTIVATED SLUDGE (municipal WWTP)** **MATURE COMPOST (MBT plant treating OFMSW and Parks and gardens waste)**	**Effluent from acidogenic fermenters treating FW initially inoculated with anaerobic digetate (mesophilic conditions) of sewage sludge**

REFERENCE ACIDOGENIC FERMENTER TREATING FW

Features:

T = 35°C

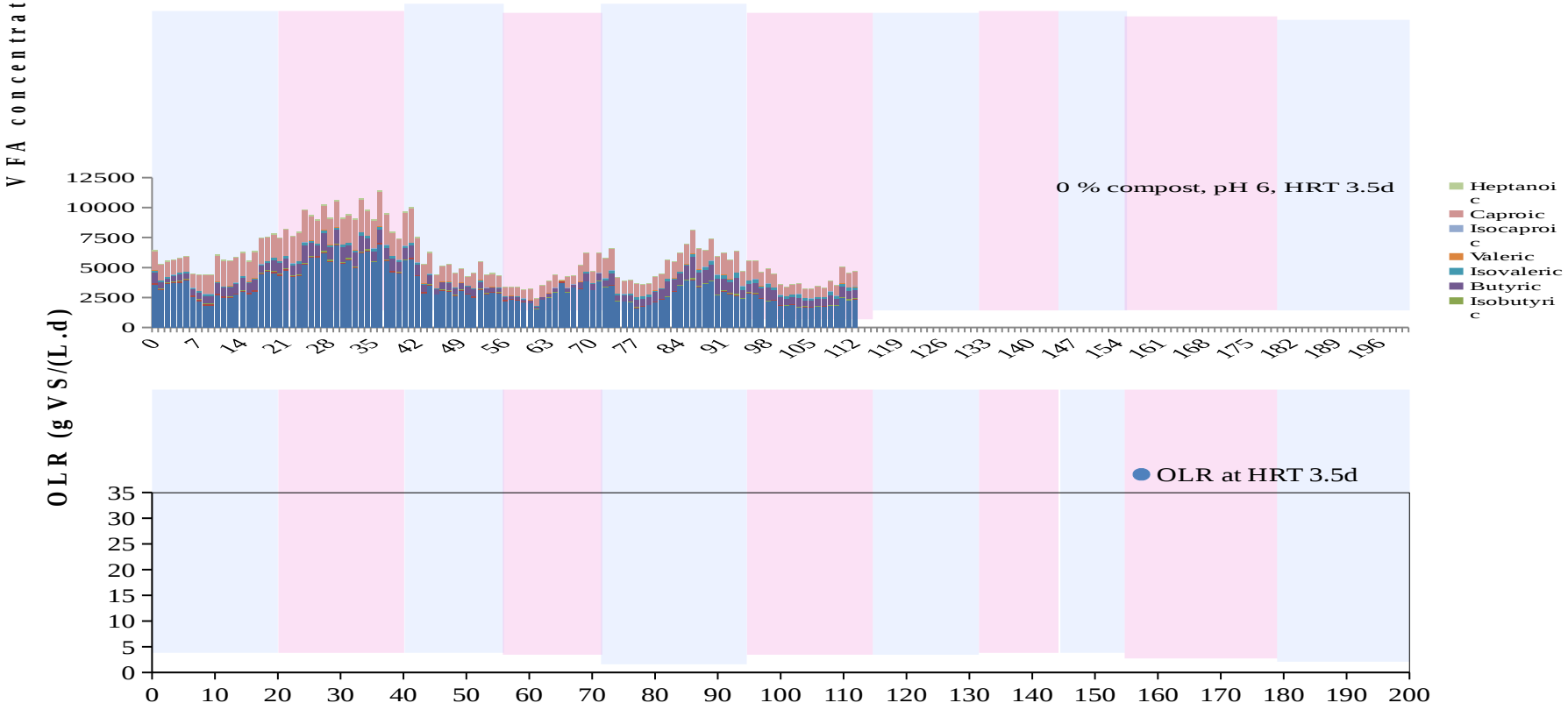
HRT 3.5 day

VS: 4.1-6.1 %w/w

pH control --> 6.0

Acetic acid and butyric acid concentrations were predominant at pH 6.0 although FW was randomly collected from a University canteen

Different collection periods

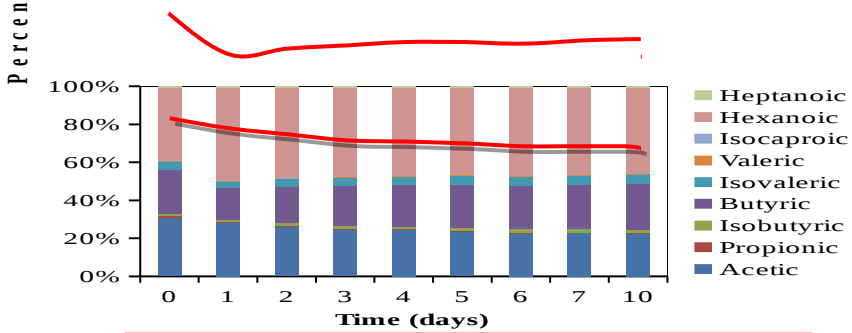


BATCH FERMENTATION ASSAYS OF FW ADDING MATURE COMPOST

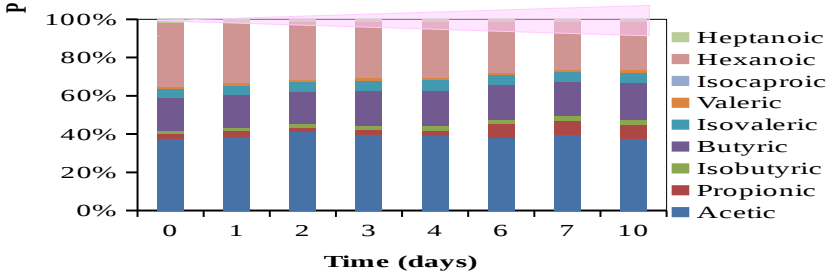
pH 6
pH 7

Experiment carried out in duplicate.
Ratio inoculum/Fresh FW : 1:1 (VS basis)

FW (% VS in the mixture)	Compost added (% ST)	VFA Improvement (%) at pH 6 (10d)	VFA Improvement (%) at pH 7
50 %	0 %	-	-
44 %	2.5 %	15.0 %	4.5%
41 %	3.5 %	12.9%	1.6%
39 %	4.5 %	9.7%	-



10 days , 2.5% mature compost pH 6



10 days , 2.5% mature compost, pH 7

BATCH FERMENTATION ASSAYS OF FW ADDING MATURE COMPOST

pH 6						
Parameter	Units	0%	2.5%	3.5%	4.5%	FW only
%VS of Food Waste in the mixture	%	50	44	41	39	100
Soluble COD at day 10	g COD/L	47.09	50.87	49.95	52.22	55.51
NH_4^+-N at day 10	mg NH_4^+-N/L	1027	1058	1033	1058	458
VFA concentration and distribution at day 10						
VFA concentration	g COD/L	9.82	10.70	10.59	10.22	2.68
Acetic Acid	%	21.5	22.3	22.0	22.7	79.0
Propionic Acid	%	0.5	0.6	0.7	0.6	4.8
Isobutyric Acid	%	2.0	1.8	1.8	1.9	2.1
Butyric Acid	%	21.0	23.6	23.8	24.5	4.9
Isovaleric Acid	%	5.7	5.3	5.0	5.3	0.7
Valeric Acid	%	0.5	0.7	0.7	0.7	2.1
Isocaproic Acid	%	0.2	0.2	0.2	0.2	0.5
Hexanoic Acid	%	47.4	44.6	44.9	43.1	5.2
Heptanoic Acid	%	1.0	0.9	0.8	0.9	0.7

pH 7						
	Units	0%	2.5%	3.5%	4.5%	FW only
%VS of Food Waste in the mixture	%	50	43	41	39	100
soluble COD at day 10	g COD/L	48.47	47.88	49.06	42.93	n.a
Initial NH_4^+-N	mg NH_4^+-N/L	728	734	727	680	n.a
NH_4^+-N at day 10	mg NH_4^+-N/L	1164	1635	1724	1803	n.a.
VFA concentration and distribution at day 10th						
VFA concentration	g COD/L	12.94	13.28	13.43	11.74	5.18
Acetic Acid	%	37.5	37.4	38.2	35.9	76.2
Propionic Acid	%	6.8	7.3	7.5	7.3	13.5
Isobutyric Acid	%	2.6	2.5	2.6	2.6	2.9
Butyric Acid	%	18.4	19.6	19.4	19.4	1.2
Isovaleric Acid	%	5.7	5.3	5.2	5.4	1.1
Valeric Acid	%	1.3	1.4	1.4	1.5	1.6
Isocaproic Acid	%	0.1	0.1	0.1	0.1	0.4
Hexanoic Acid	%	25.7	24.8	24.3	26.3	1.6
Heptanoic Acid	%	1.7	1.6	1.4	1.5	1.5

n.a.: Not analysed

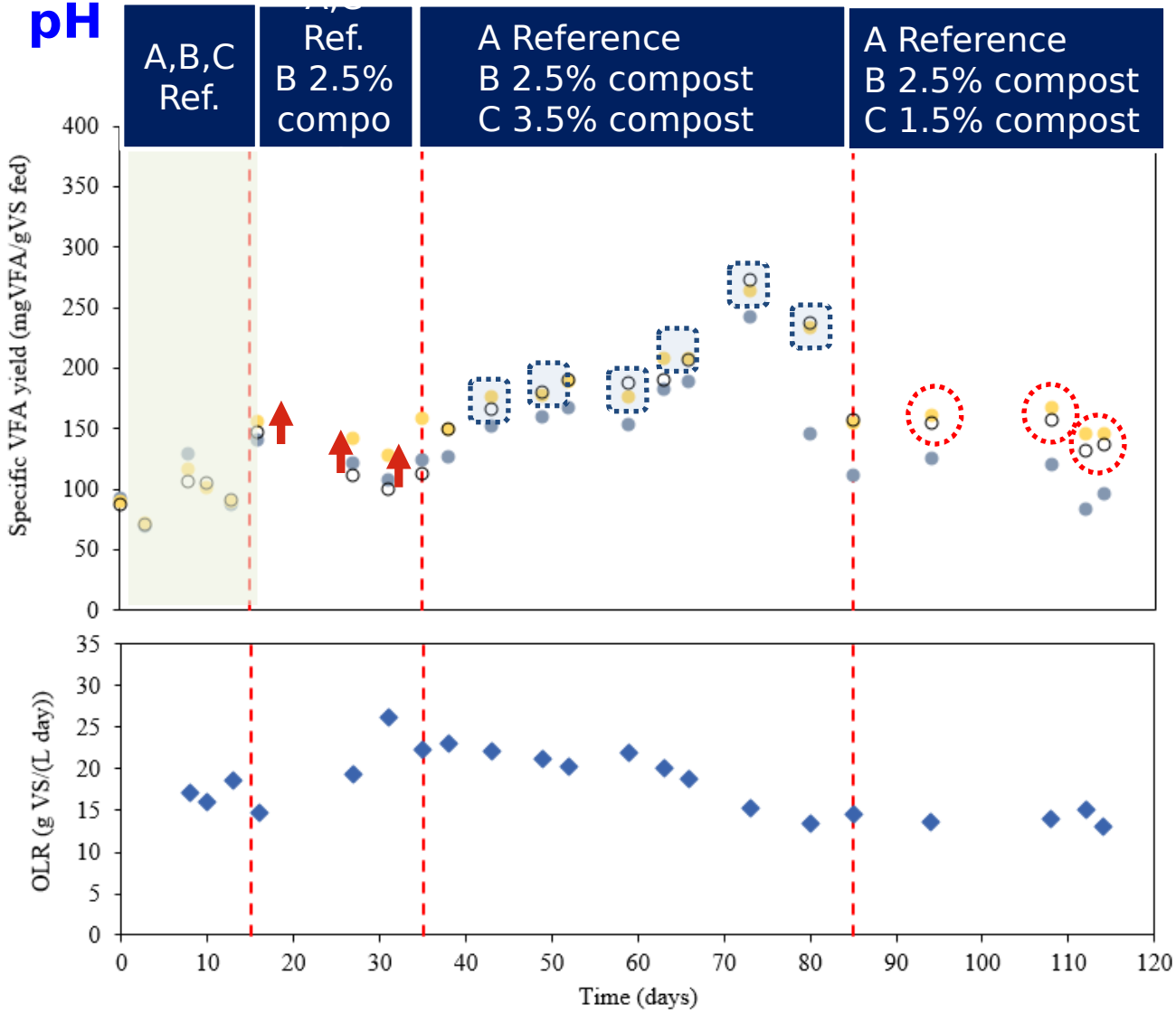
Mature compost Higher solubilisation and ammonium release

Mature compost Higher butyric acid production

Mature compost Higher ammonium release

Mature compost Similar distribution of VFA

SEMI-CONTINUOUS OPERATION ACIDOGENIC FERMENTER



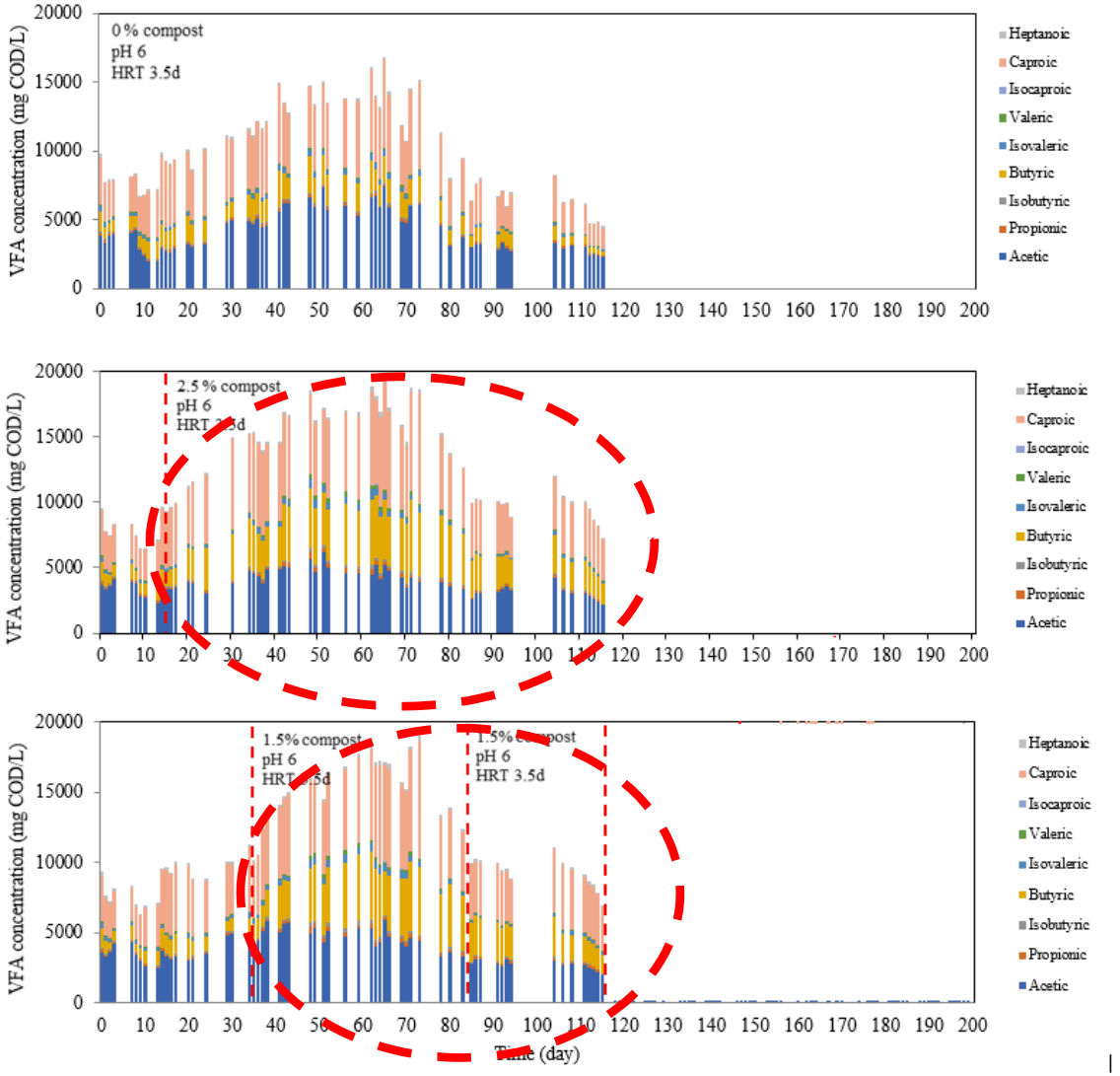
VFA production enhancement using 2.5% w/w compost. Major impact at lower OLR

11-19% higher (%VS infl. 5.5-6.1%)
29-51% higher (% VS infl. 3.8-3.9%)

Similar VFA production using 2.5% and 3.5 w/w compost

Slightly lower VFA production when using 1.5% instead of 2.5 w/w compost

SEMI-CONTINUOUS OPERATION ACIDOGENIC FERMENTER



- **VFA production** could be **boosted** up in the beginning and maintained its dominance during the experiment, with **compost** doses between **1.5-3.5%w/w at pH 6.**
- **Higher butyric acid proportion when compost is added** (from up to 12.2% (COD basis) in the reference reactor to up to 23.5%)
- **Higher solubilisation** expressed in terms of **sCOD** and **NH_4^+-N release** was detected in the fermenters working **with mature**

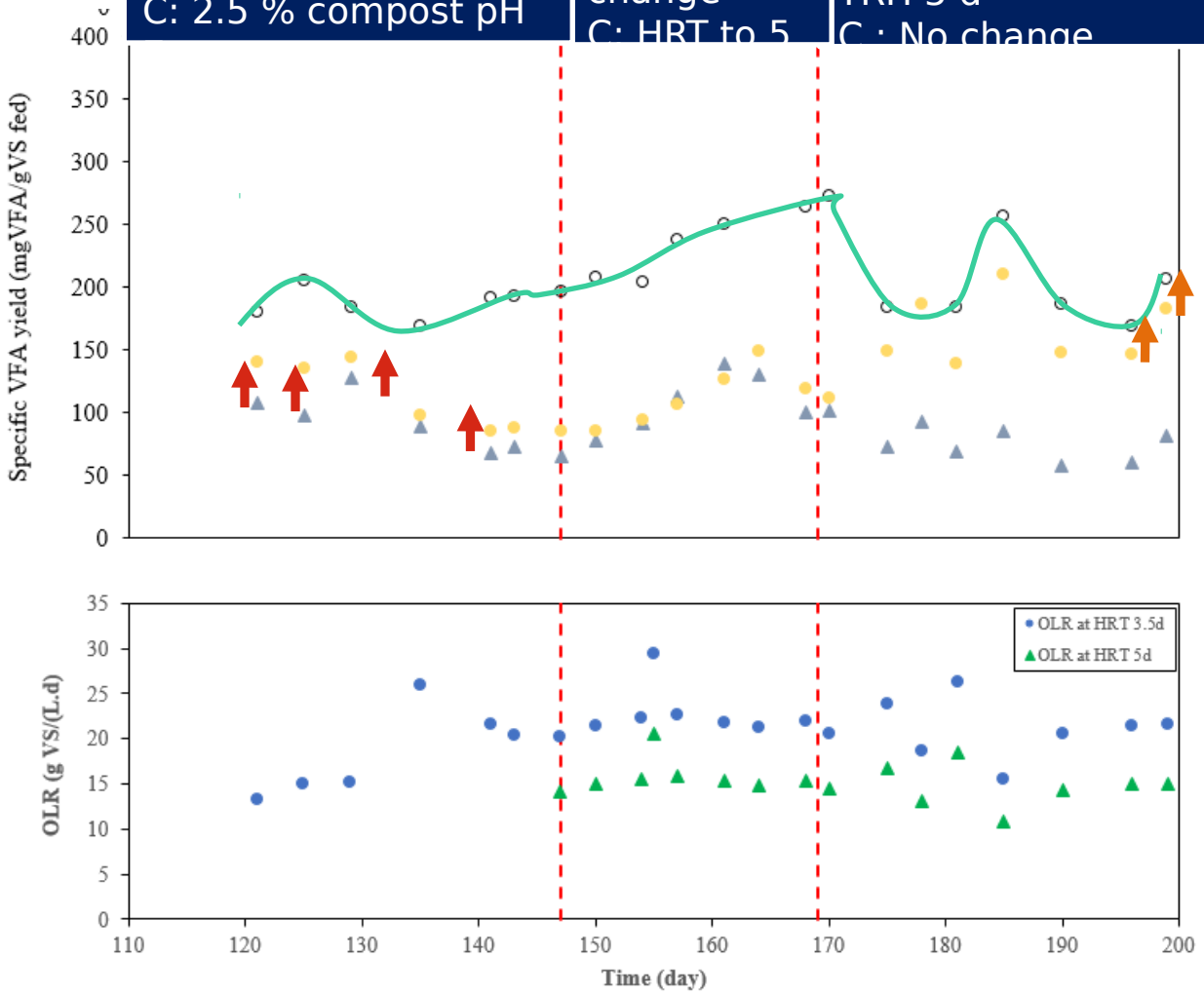
SEMI-CONTINUOUS OPERATION ACIDOGENIC FERMENTER

pH (

B: 2.5 % compost pH 6
C: 2.5 % compost pH

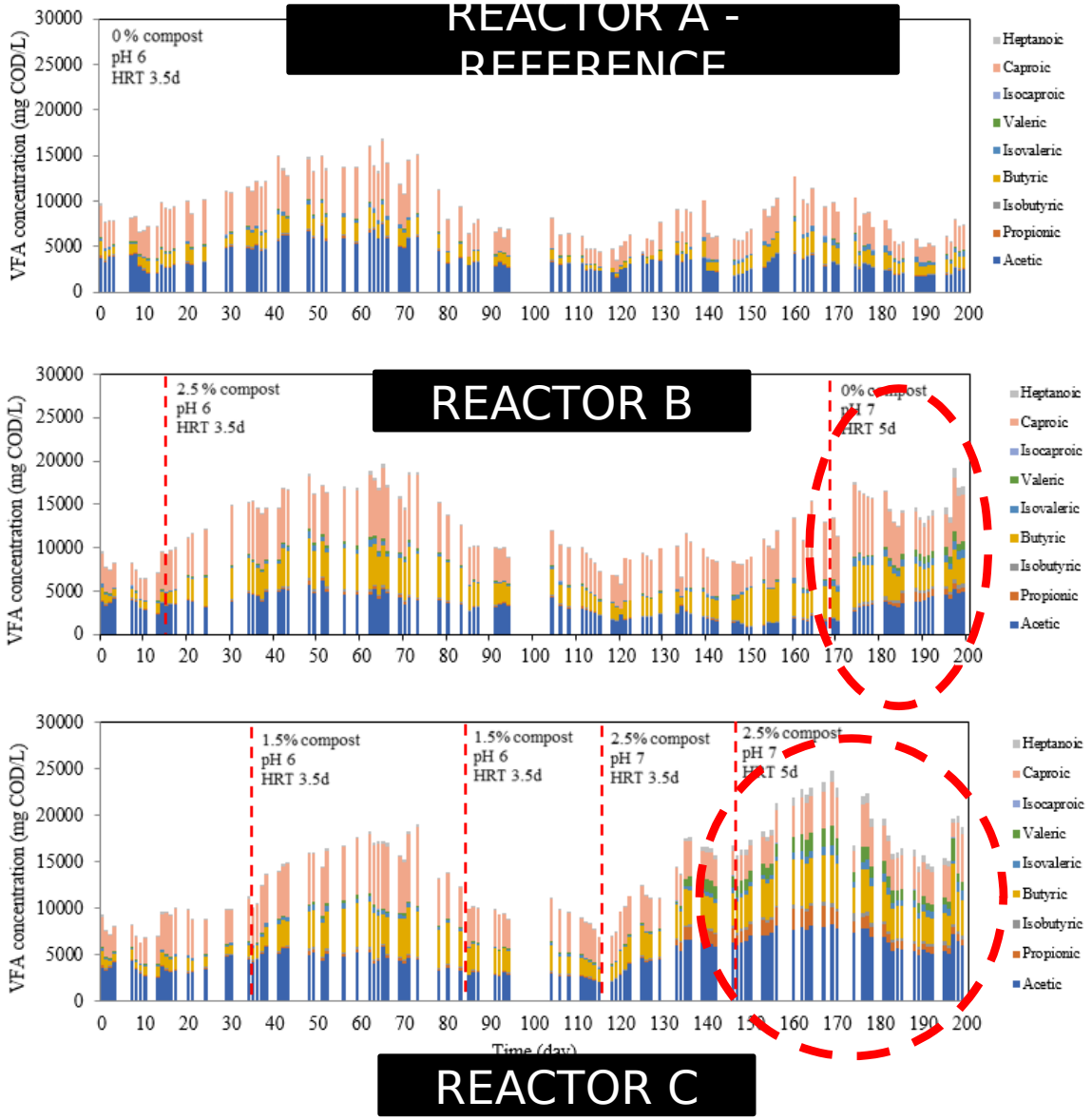
change
B: No change
C: HRT to 5

A : No change
B: 0% compost, pH 7, TRH 5 d
C : No change



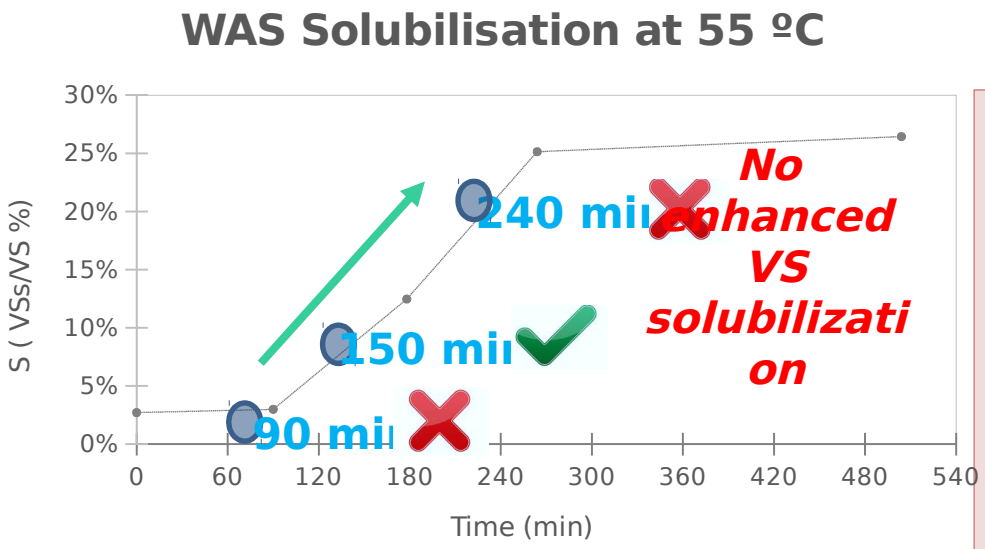
High VFA production enhancement using 2.5% w/w compost at pH 7

SEMI-CONTINUOUS OPERATION ACIDOGENIC FERMENTER



- At pH 7 with addition of 2.5% mature compost, an **improvement of 186% of the VFA concentration (on COD basis) were recorded with respect to the reference reactor.**
- At **pH 7**, a **rise in propionic** (from 1.6 to 7.7%), **valeric** (from 0.8 to 5.6%) **acids** production was observed as compared to

SOLUBILISATION ASSAYS WITH PRETREATED WAS AT 55ºC



Experiment carried out in duplicate with bottles of 1L of working volume.

Every 60-90 min, the TsS and **VsS** are analysed to determine the **solubilisation (SsV/SV)** of WAS

- A growth of VS solubisation **from 3% to 26% at 9h** was observed.
- **4h 30 min** were enough time of WAS autohydrolysis with

Pretreated WAS (55ºC at 4h) + Food Waste

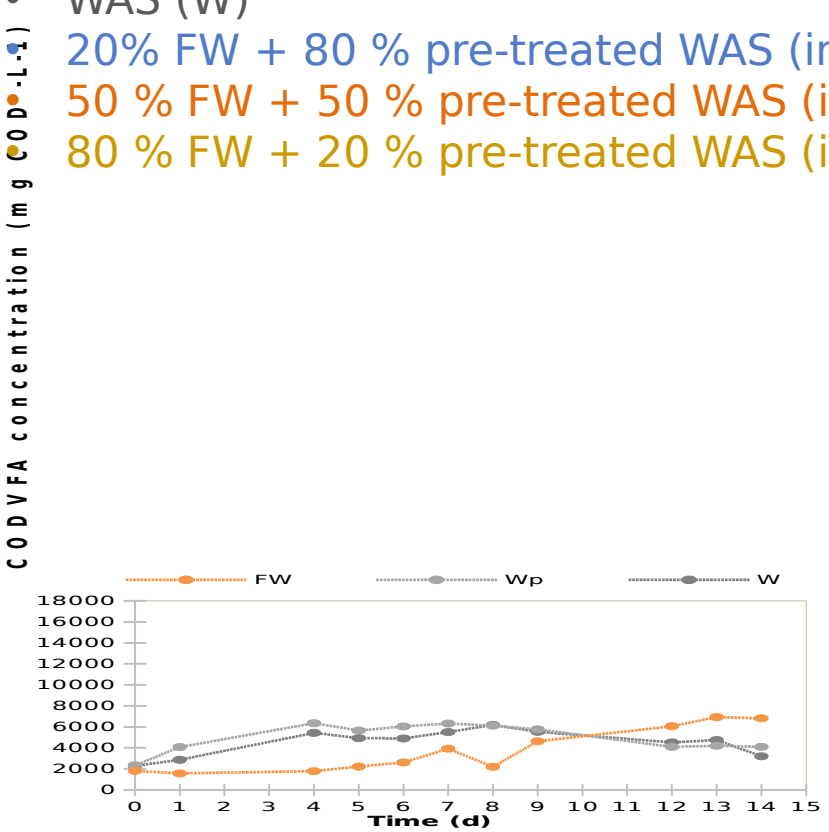
35ºC

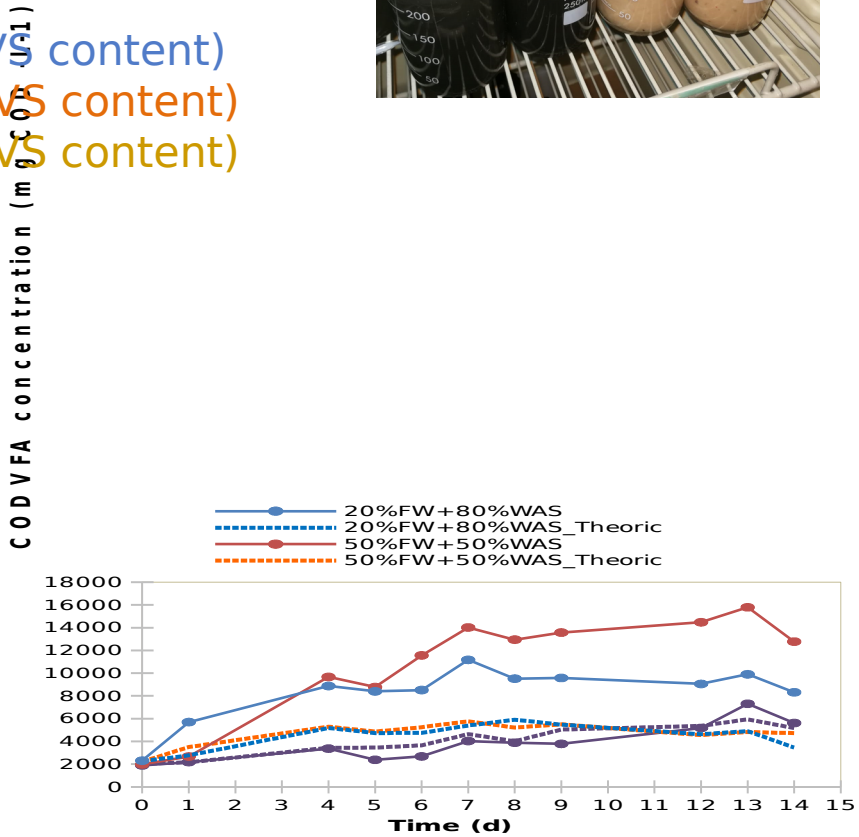
Food Waste ***Hydrolysis and VFA production*** enhancement

PRETREATED WAS (55ºC AT 2.5 H) + FOOD WASTE

Discontinuous assays:

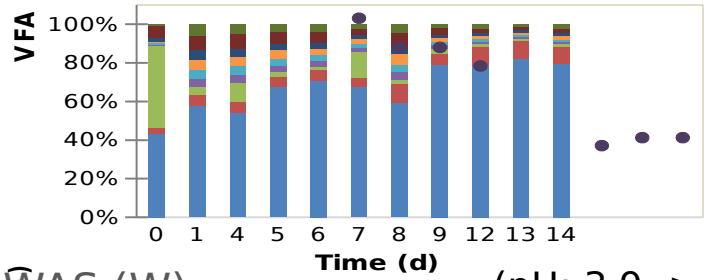
- Food Waste (FW)
- Pre-treated WAS (Wp)
- WAS (W)
- 20% FW + 80 % pre-treated WAS (in VS content)
- 50 % FW + 50 % pre-treated WAS (in VS content)
- 80 % FW + 20 % pre-treated WAS (in VS content)





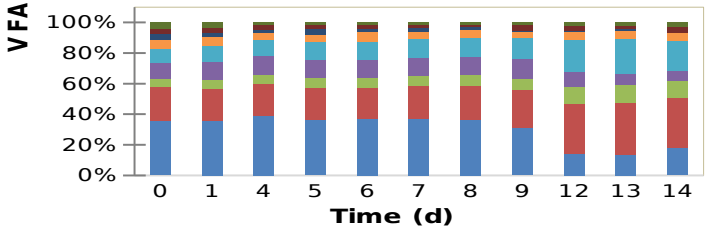
PRETREATED WAS (55ºC AT 2.5 H) + FOOD WASTE

Food Waste (FW)



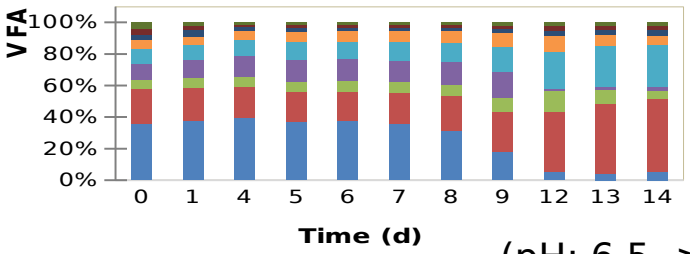
(pH: 3.9 -> 3.7)

WAS (W)



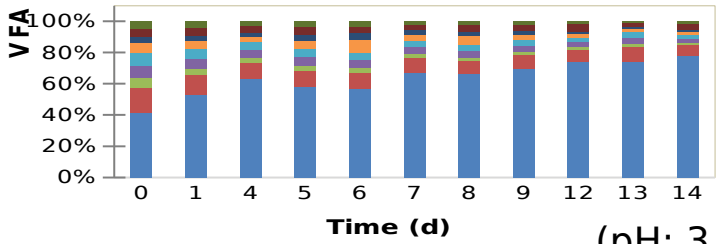
(pH: 6.4 -> 7.9)

Pre-treated WAS (Wp)



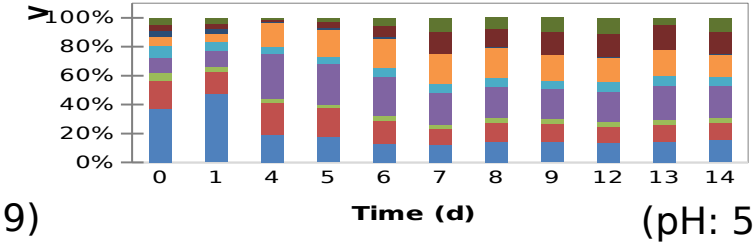
(pH: 6.5 -> 7.8)

80 % FW + 20 % pre-treated WAS (in VS content)



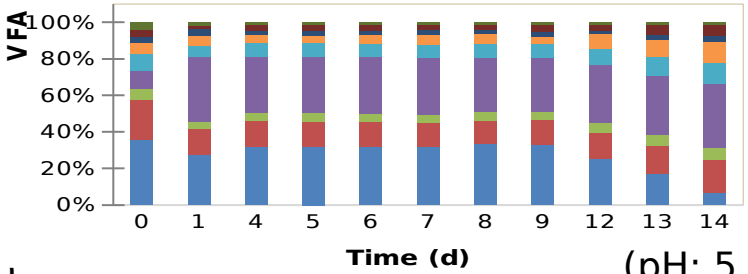
(pH: 3.9 -> 4.6)

50 % FW + 50 % pre-treated WAS (in VS content)



(pH: 5.5 -> 5.9)

20% FW + 80 % pre-treated WAS (in VS content)



(pH: 5.8 -> 7.8)

CONCLUSIONS

The addition **of 2.5% w/w of mature compost** to a semi-continuous acidogenic fermenter treating FW at mesophilic conditions (35ºC), **pH 6** and HRT of 3.5 days led to an **improvement of the VFA yield** up to 51.2 % (on VFA basis)

The mature compost dosage at pH 6 resulted in a **higher percentage of butyric acid** on COD basis in the fermentation broth, increasing from up to 12.2 % (0% compost addition) to up to 23.5 % (2.5% compost addition).

When pH was changed **from pH 6 to pH 7**, **VFA production was boosted** and a higher production of propionic and valeric acids was recorded with respect to the reactor working at pH 6.

Regarding WAS pretreatment, **solubilisation of WAS at 55ºC from 3% to 25% took place in 4h**.

Synergies in VFA production when mixing pretreated **WAS at 55ºC during 2.5h** and **FW** were observed for mixtures containing **up to 50% VS of FW.** No synergies were observed when mixing WAS at 55ºC during 1.5 and 4 h.

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