Valorisation of cellulosic sludge by fermentation process: VFAs production and phosphorus recovery

UNIVERSITÀ
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Small Water and Wastewater
Systems

5th IWA
Specialized Conference on
Resources-Oriented Sanitation

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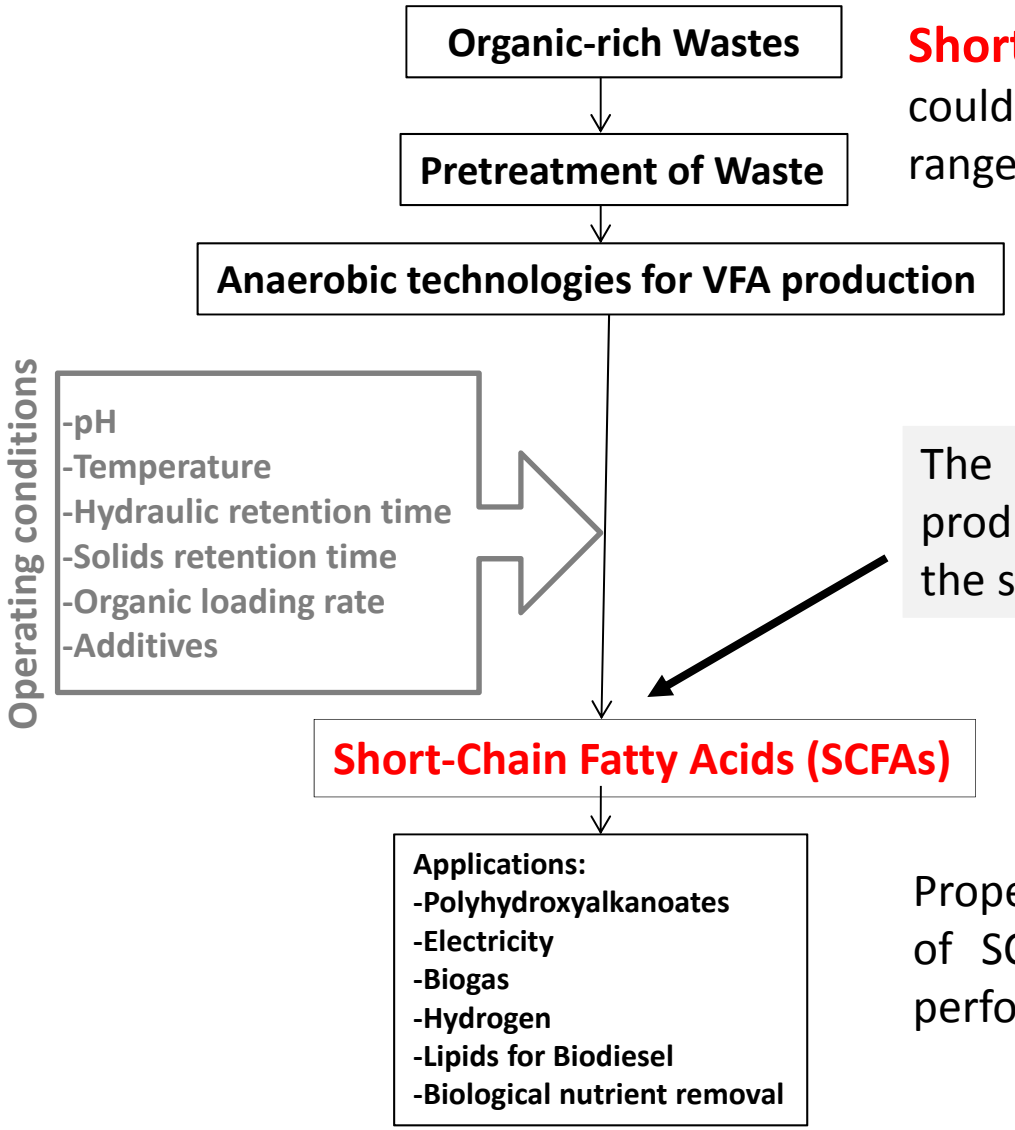
Background

- Municipal wastewater contains around **100-120 gCOD/(inhabitant per day), however diluted in 250-350 L/(inhabitant per day);**

- Around 50-80% of the suspended solid can be efficiently removed by the sieving of the wastewater, in which up to 35% is toilet paper (Ruiken et al., 2013, Water Research);

- The sewage sludge might be considered as a **challenging feedstock** to be processed for bio-based applications (waste-to-chemicals and bio-product value chain);

Production and Application of Waste-derived SCFAs



Short–Chain Volatile Fatty Acids (SCFAs) could be considered intermediates for a wide range of applications

The operating conditions for SCFAs production should be addressed based on the substrate and the fate of the VFAs

Proper process control can manipulate the **type** of SCFAs produced, which is critical to the performances of the downstream applications.

Lee et al., 2014. Chemical Engineering Journal.

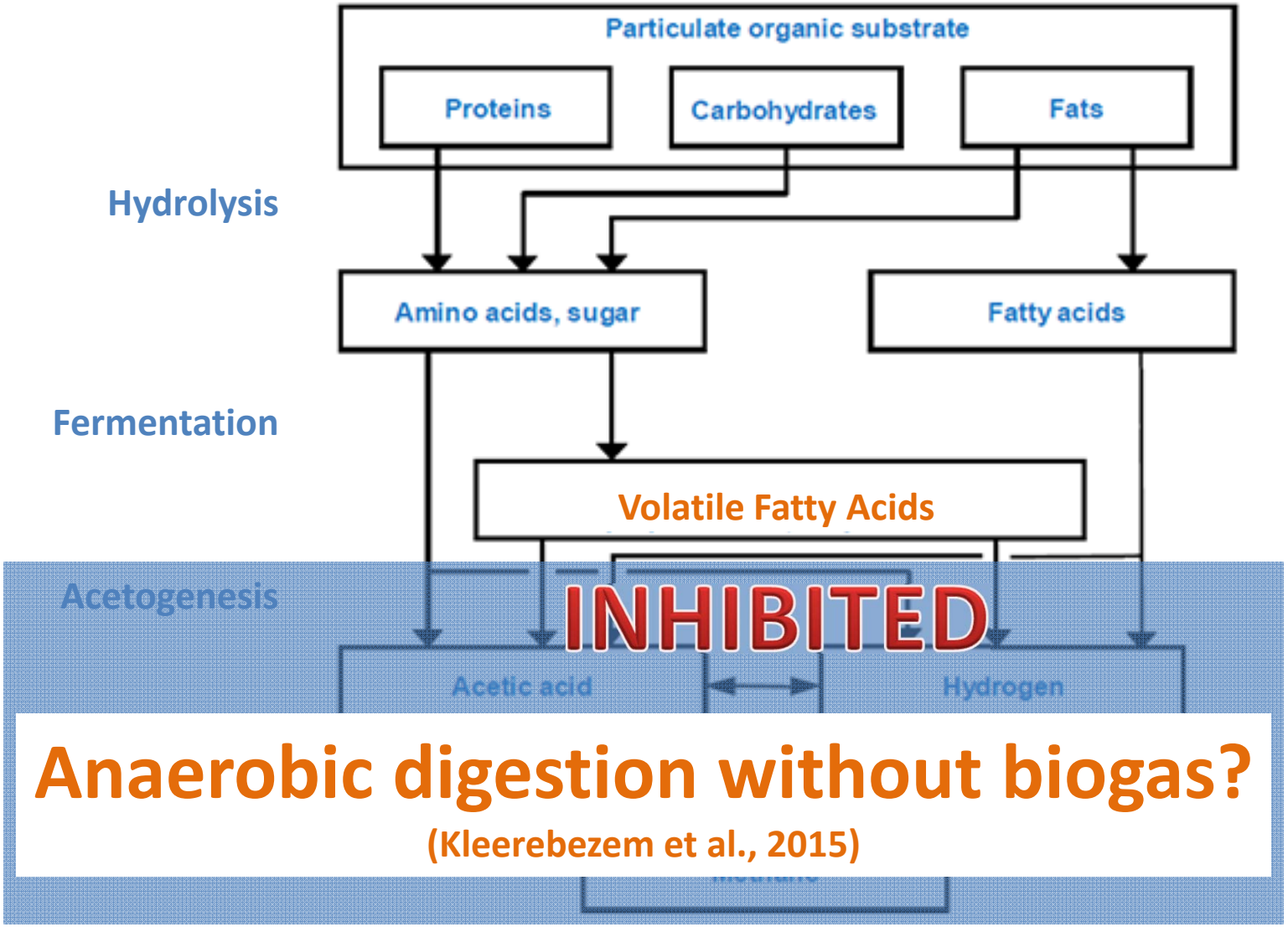
Anaerobic biodegradation of toilet paper

Up to now, the utilization of cellulosic sludge has been investigated for the production of **biogas,** the production of thermal and electric energy and **compostable material**;

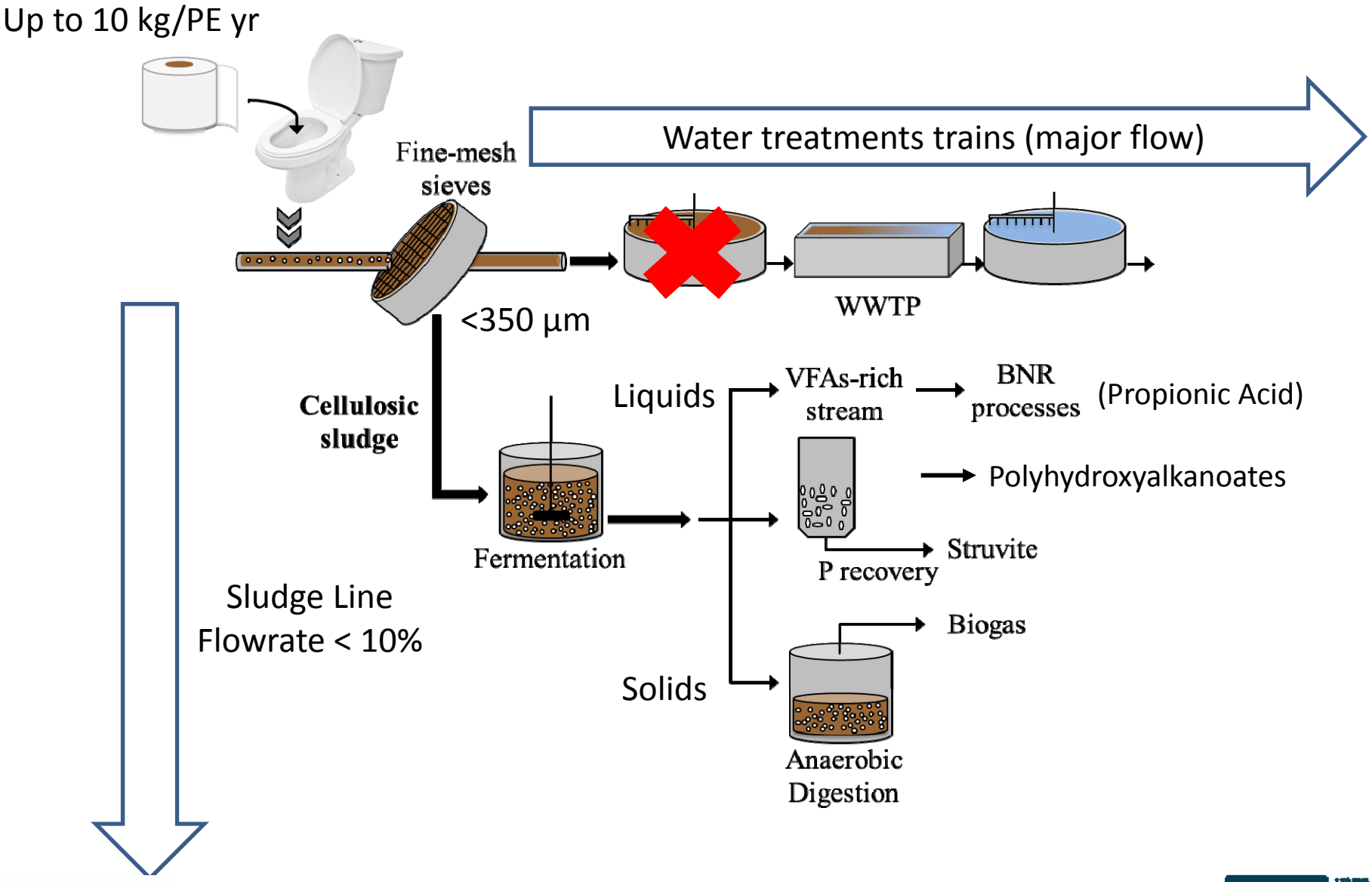
Condition	pH	°C	Type fibre	Removal%	Days
Anaerobic	7.0	30	Toilet paper from recycled paper	100	8
Anaerobic	7.0	24	Toilet paper from recycled paper	100	12
Anaerobic	7.0	9	Toilet paper from recycled paper	10	20
Anaerobic	7.0	24	4 layer type 1 toilet paper	100	15
Anaerobic	7.0	24	4 layer type 2 toilet paper	100	20
Anaerobic	7.0	24	Sieving material 50% SS removal	100	20
Anaerobic	7.0	17	Sieving material 50% SS removal	50	20
Anaerobic	5.0	24	Toilet paper from recycled paper	40	20

Ruiken et al., 2013

Anaerobic biodegradation of cellulosic sludge



Valorization of cellulosic sludge



Objective

- To investigate the production of Volatile Fatty Acids (VFAs) and the phosphorus (PO_4^{3-}-P) release from the fermentation of cellulosic sludge.
- To study the potential recovery of phosphorus by struvite crystallisation.

Characteristics of the cellulosic sludge

- Origin: WWTP of Verona municipality (North of Italy);
- Cellulosic sludge used was prepared by mixing primary sludge + toilet paper;
- The toilet paper was kept in wastewater for 4 h to achieve a cellulosic sludge with similar characteristics to those found in WWTPs

Parameter	Units	Cellulosic Sludge
TS	g/L	50-55
VS	%VS	80-85
total COD	gCOD/gVS	1.0-1.1
soluble COD	mgCOD/gVS	45-50
TN	mgN/gVS	30-35
TP	mgP/gVS	10-15
Content of cellulose	%TS	35-38

Outline of the batch cellulosic fermentation experiments

N° Experiment	Temperature (ºC)	Initial fermentation pH
1-4	37	6.3 (Uncontrolled),8,9,10
5-8	55	6.3 (Uncontrolled),8,9,10
9-12	70	6.3 (Uncontrolled),8,9,10

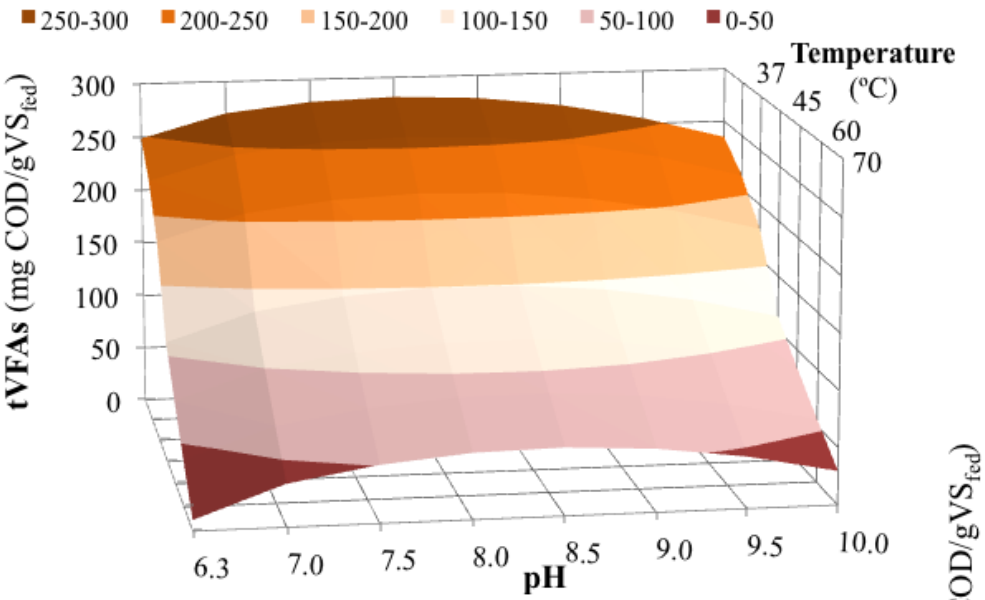
The response surface methology (RSM) was applied:

$$Y(z) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{1,2} x_1 x_2 + \beta_{1,1} x_1^2 + \beta_{2,2} x_2^2$$

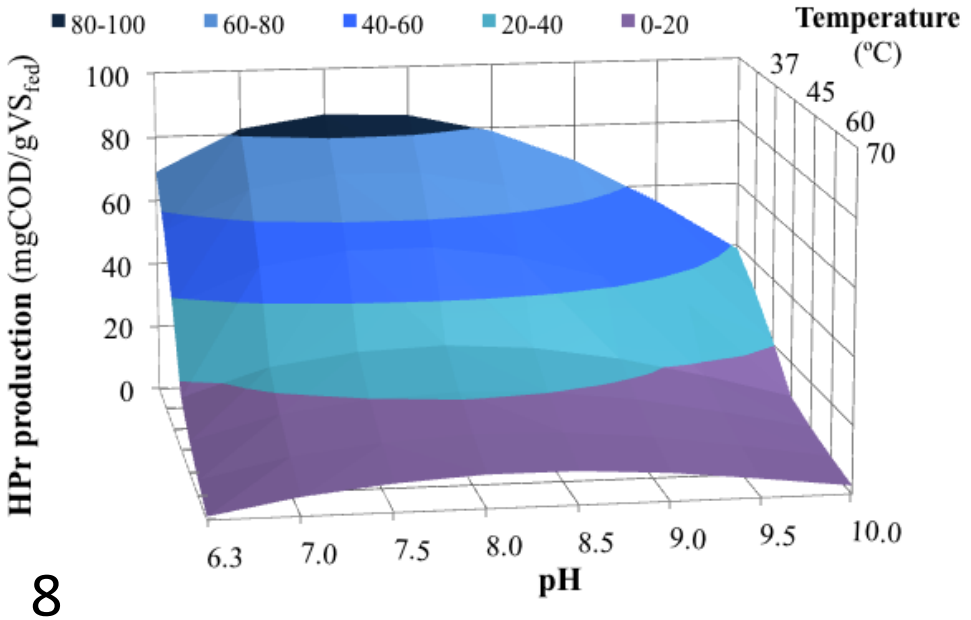
- ***Y(z)***: propionic acid production (mg COD/g Vs_{fed})
- X_1: initial pH
- X_2: temperature

3D Surface plots: SCFA and Propionic acid production

SCFA production

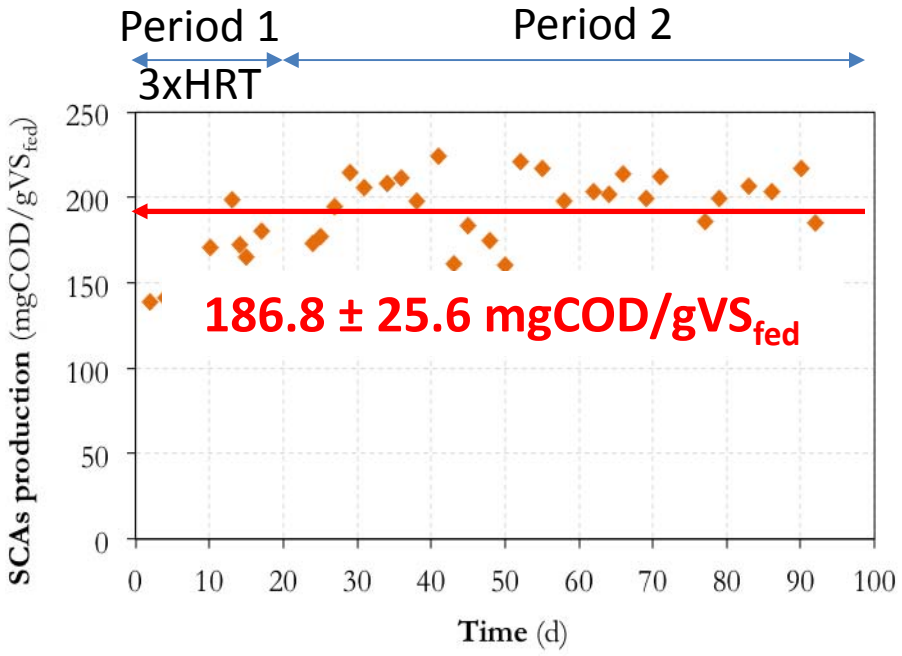


Propionic acid production

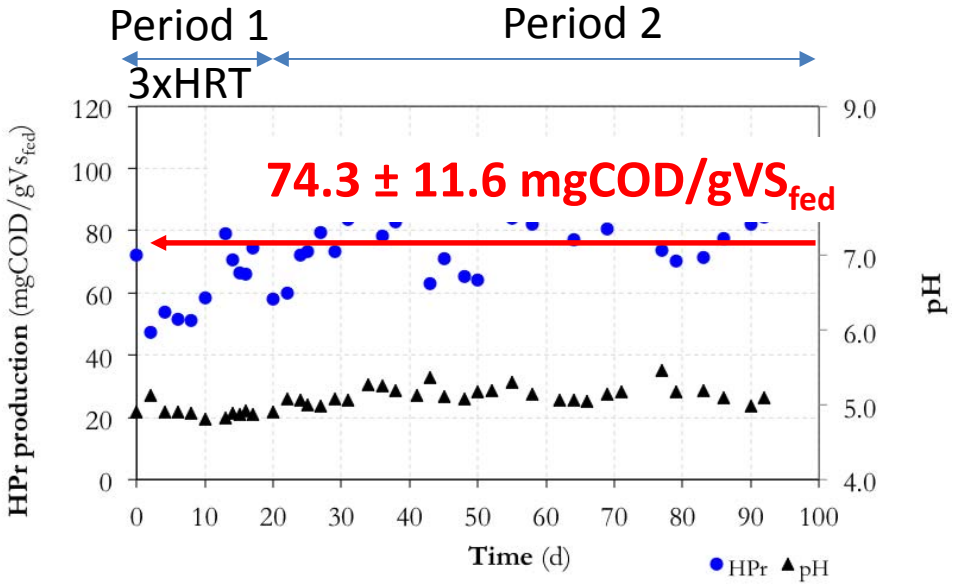


- High SCFAs and HPr production:
  - T: 37 ºC
  - HRT: 4 d
  - Initial pH range: 7.5 - 8.5 → 8

Sequencing Batch Fermentation Reactor (SBFR): SCFA and propionic acid (HPr) production



Period	Cellulosic Sludge content (%)	Influent pH
I	34.6	6.2 (Uncontrolled)
II	33.9	8.0



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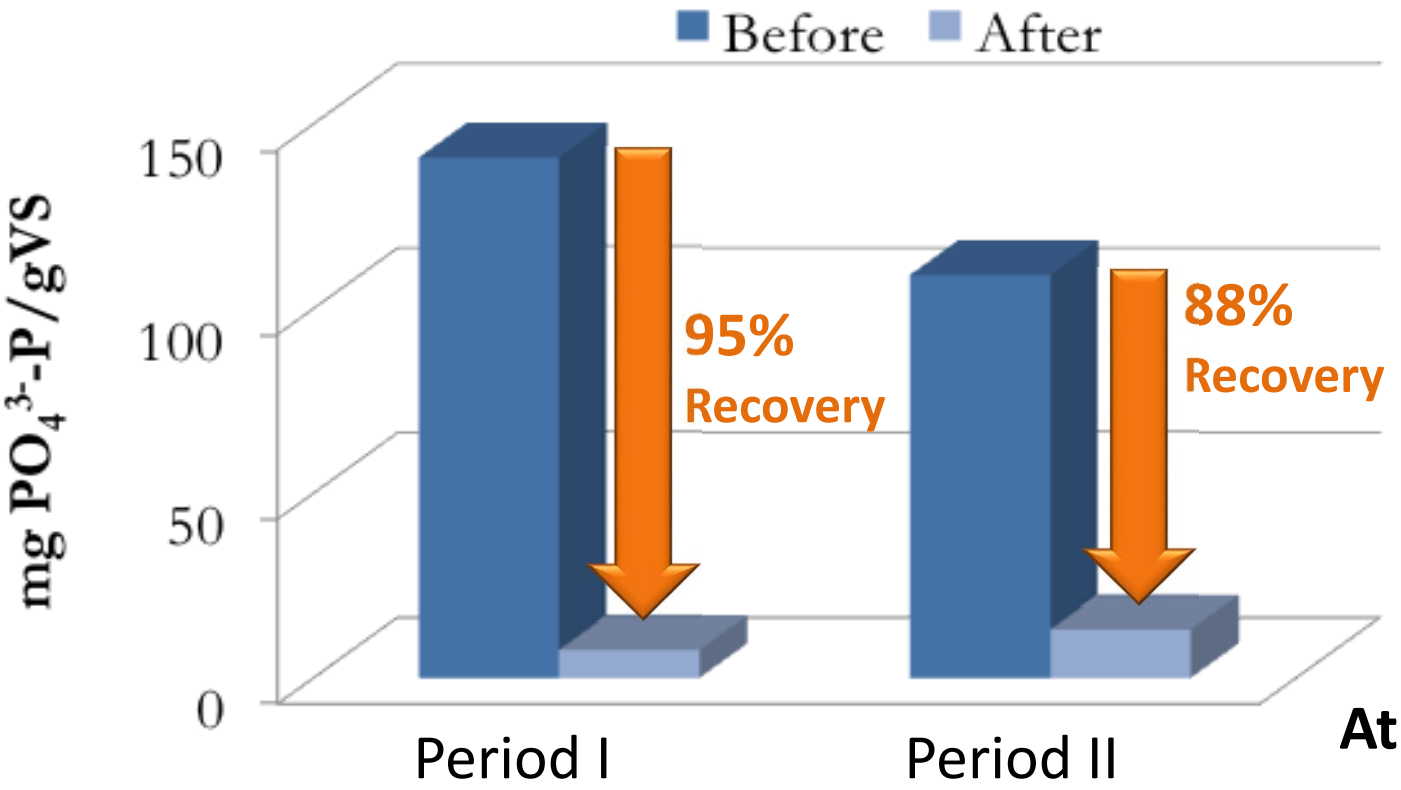
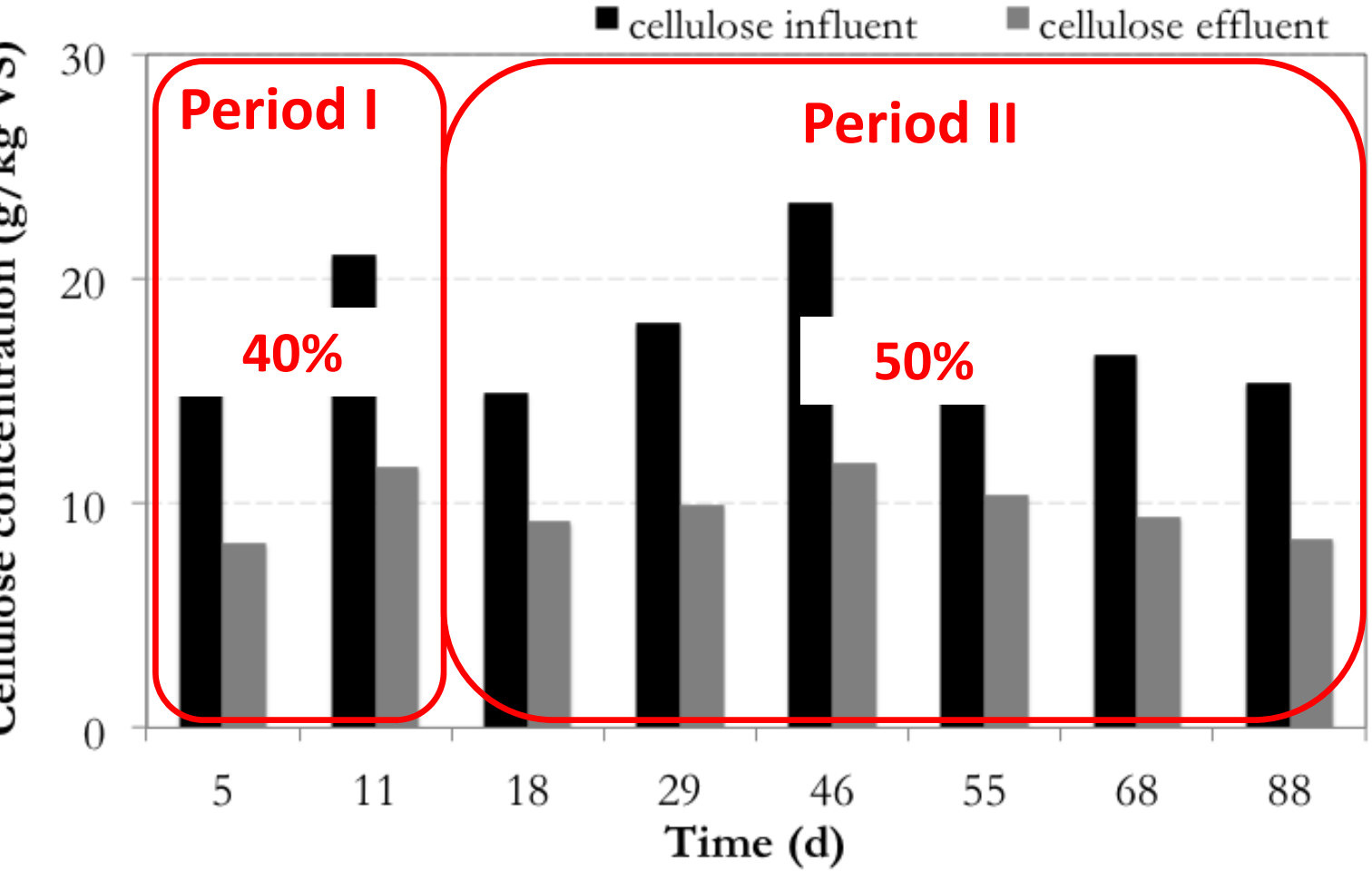
ecovery during cellulosic sludge fermentation

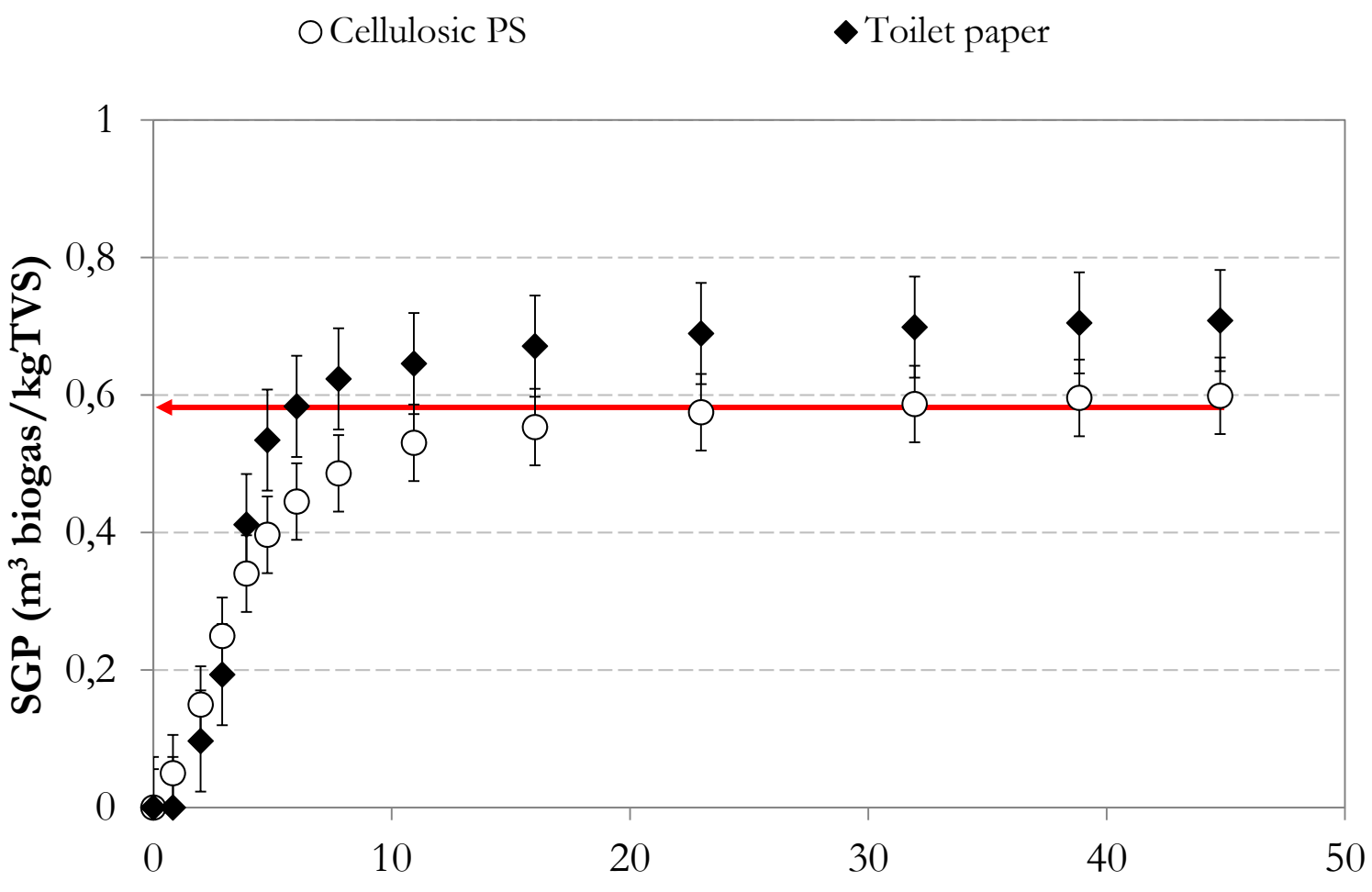


At pH: 8.5

Cellulose biodegradation



ecific gas production of the cellulosic sludge



Conclusions

he VFAs produced from the cellulosic sludge fermentation are low cost arbon source and intermediates for a wide range of applications

he fermentation of cellulosic sludge at **mesophilic conditions** and at **nfluent pH of 8** can be a suitable way to produce **high concentrations of CFAs** (186.8 ± 25.6 mg COD/g VS_{fed});

t these fermenting conditions the main VFAs produced were **acetic and ropionic acids**, with a molar ratio of 0.84 mol HPr/mol HAc;

uring the fermentation high concentrations of **PO_4^{3-}-P and NH_4^+-N** are eleased, which could be **recovered** by **struvite crystallisation (up to 10-15 Struvite/kgTVS fed)**.

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Thank you for your attention

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