Polyhydroksyalkanoate (PHA) production from sludge

Sub-project of Biosykli – Circular Bioeconomy in Lahti Region

Merja Kontro
University of Helsinki
Faculty of Biological and Environmental Sciences,
Ecosystems and Environment Research Programme

UNIVERSITY OF HELSINKI
FACULTY OF BIOLOGICAL AND ENVIRONMENTAL SCIENCES

UNIVERSITY OF HELSINKI

16.12.2020

Programme for Sustainable Growth and Jobs

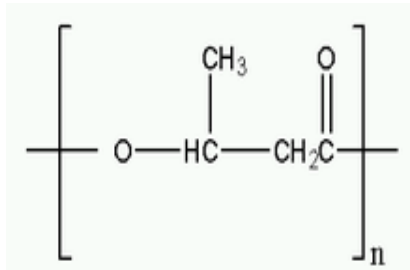
THE REGIONAL COUNCIL OF PÄIJÄT-HÄME

Leverage from the EU 2014–2020

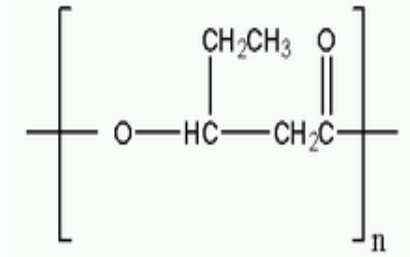
European Union
European Regional Development Fund

Polyhydroxyalkanoates (PHA)

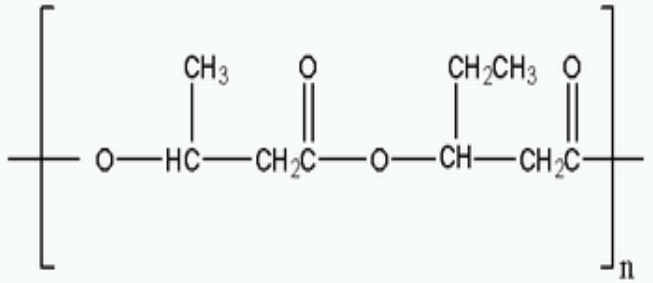
- Polyhydroksyalkanoates are most commonly polyesters of hydroxybutyrate (HB) and/or hydroksyvalerate (HV)
- PHAs are bacterial storage lipids
- PHAs are currently produced commercially mainly by pure cultures
- The trend is to move to producing PHAs from waste material using bacterial mixed cultures



PH3B



PHV



PHBV

Why polyhydroxyalkanoates?

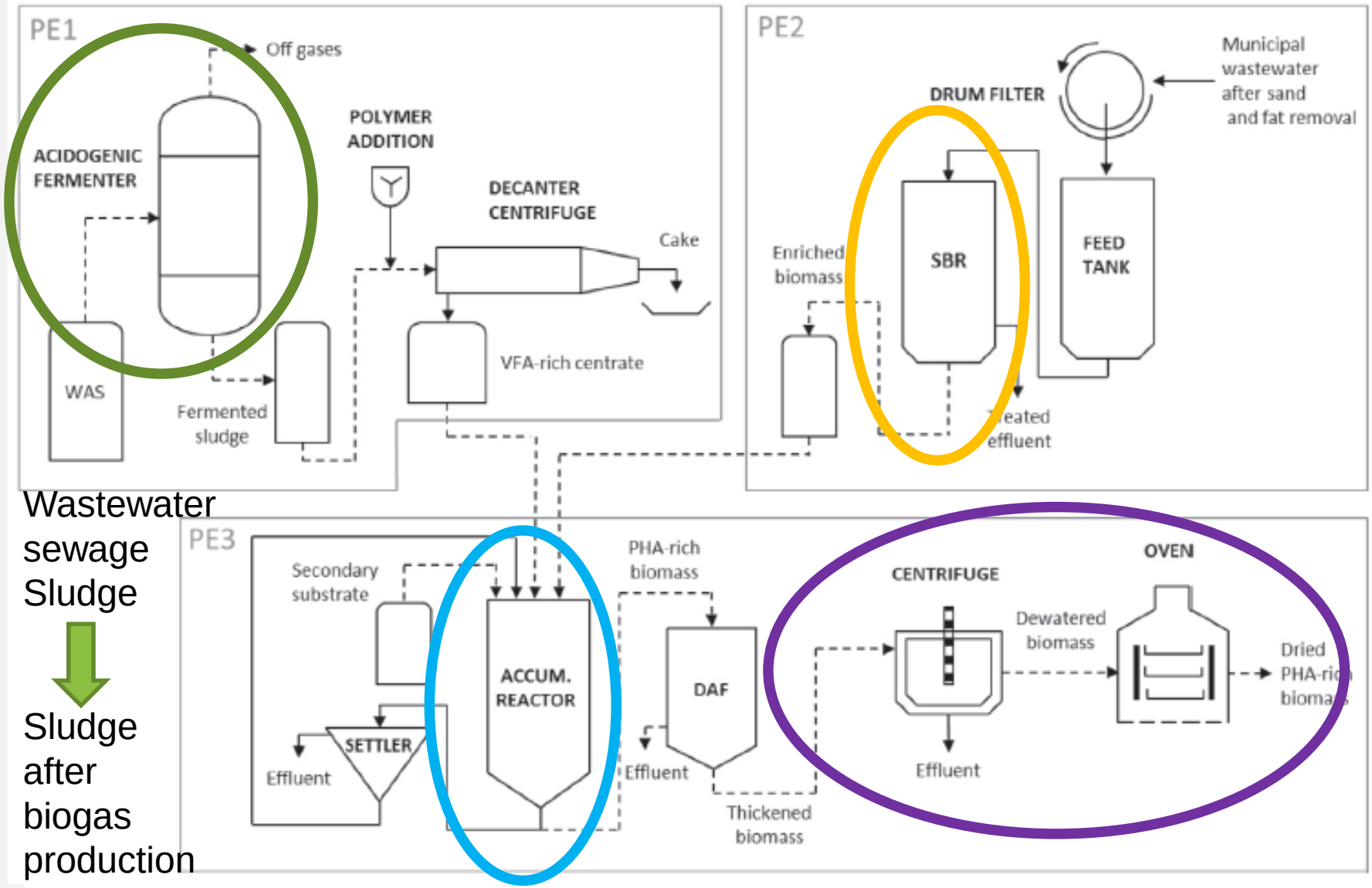
- Switching from fossil fuels to recyclable carbon sources in plastic raw materials will mitigate the climate change

- PHAs are biodegradable/compostable plastics raw materials
  => reduce environmental problems related to plastic waste

- Transforms waste organics into plastics, that can even be considered as carbon sinks

- The possibility of using low organic waste is also being explored (waste with carbon >10% may not be disposed in landfills)

What is required?



Wastewater sewage Sludge

Sludge after biogas production

Bioreactor for

1. Biomass hydrolysis
2. Cultivation of PHA accumulating bacteria
3. PHA accumulation
4. Down-stream processing

Recovery of other value components

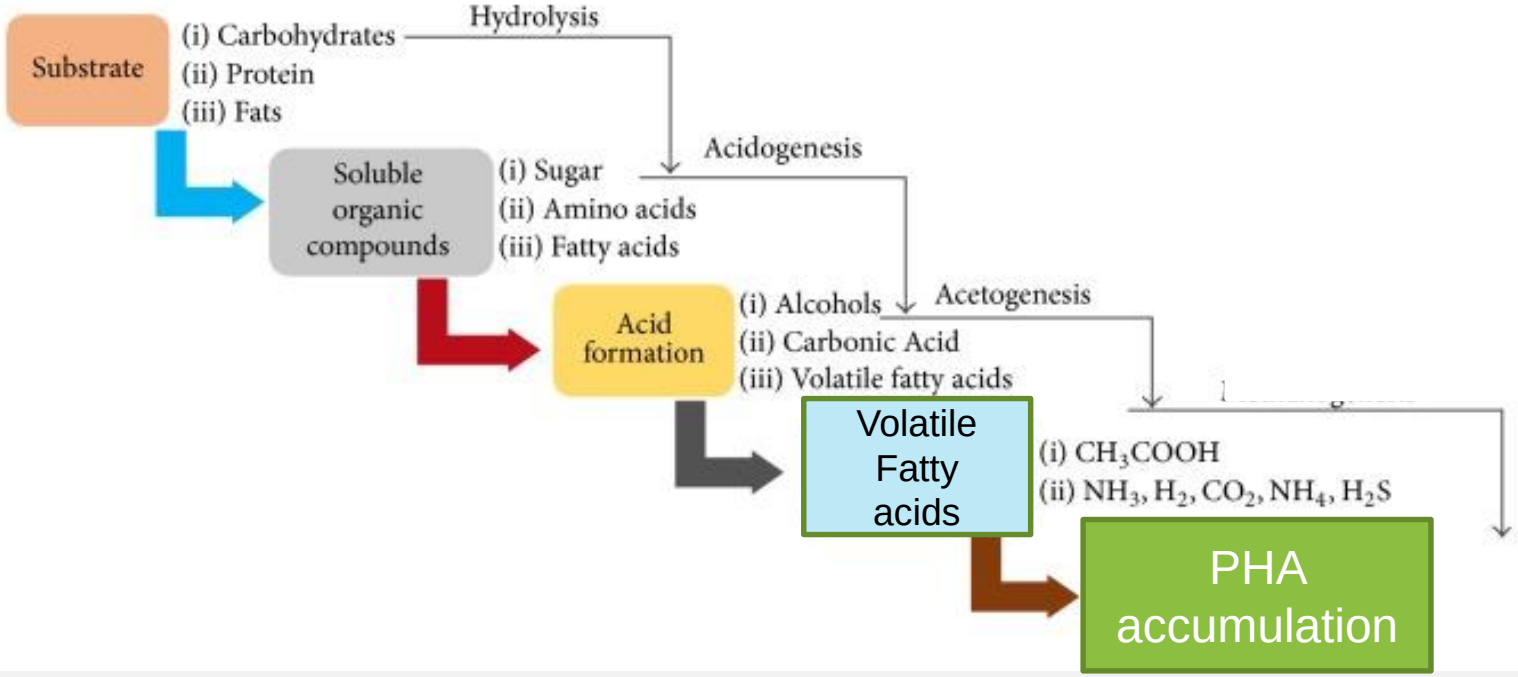
Morgan-Sagastume et al. 2015
Bioresource Technology 181, 78-89

Transforming waste to PHAs

Merja Kontro
16.12.2020

- Bioreactor for biomass hydrolysis
- The same process as
  - in the biogas production or
  - in the early stages of composting
- Difference: **nutrients (C/N or C/P) limiting microbial growth** =>

  Carbon hydrolysed, and after hydrolysis accumulated as PHA instead of using carbon for microbial growth



Accumulation of fixed solids

- The enriched fixed solids prevent biomass hydrolysis

  => Different microbial communities are required for high and low carbon bioreactors

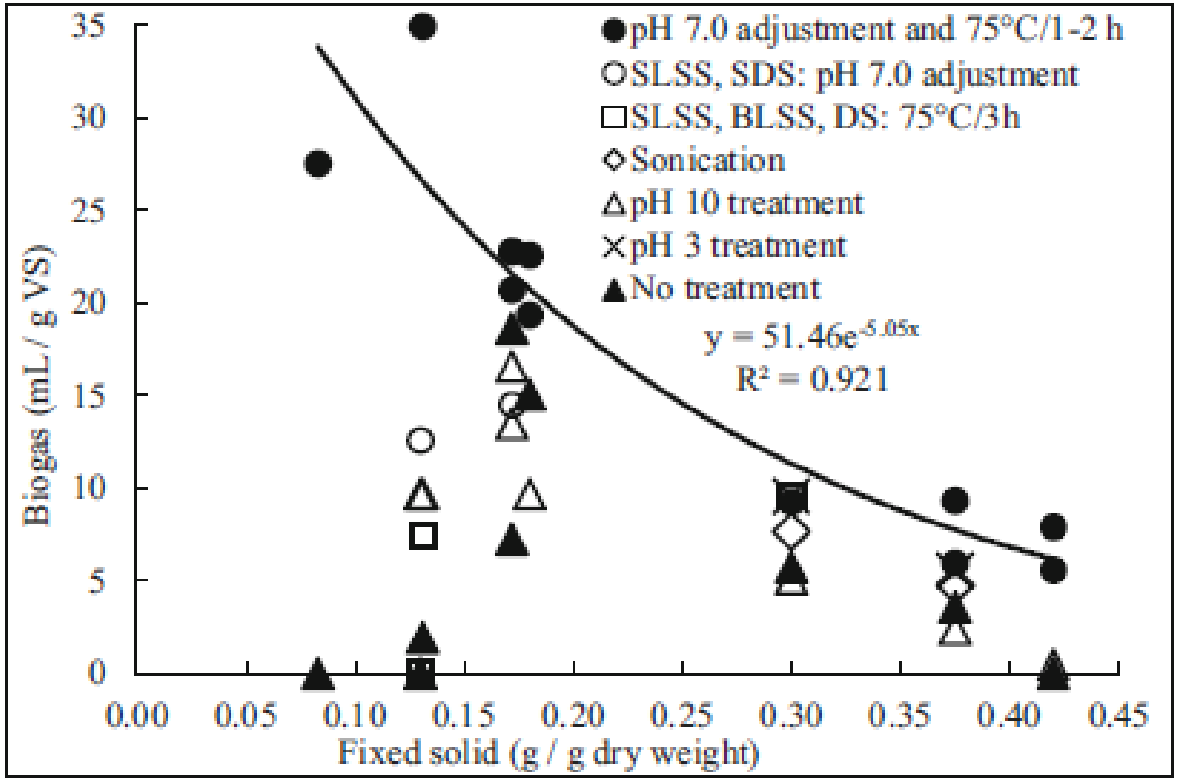


Fig. 5 Biogas yields in different treatments of E2 as a function of the fixed solid content (the average of standard deviations, 3.3 mL/g VS; $n = 3$)

Kouzi, A., Puranen M, Kontro, MH 2020 Evaluation of the factors limiting biogas production in full-scale processes and Increasing the biogas production efficiency. Environmental Science and Pollution Research, 27, 28155-28168

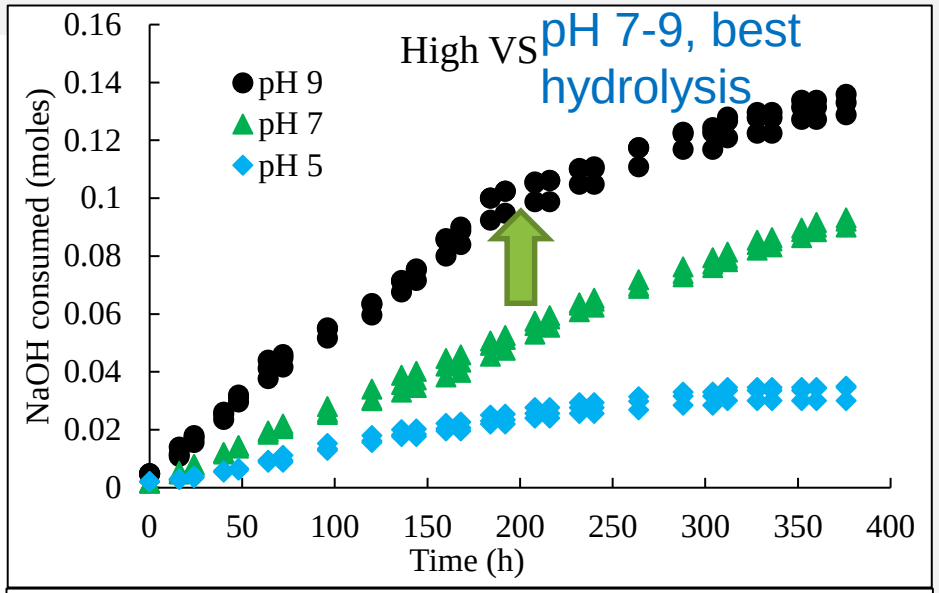
Hydrolysis bioreactors

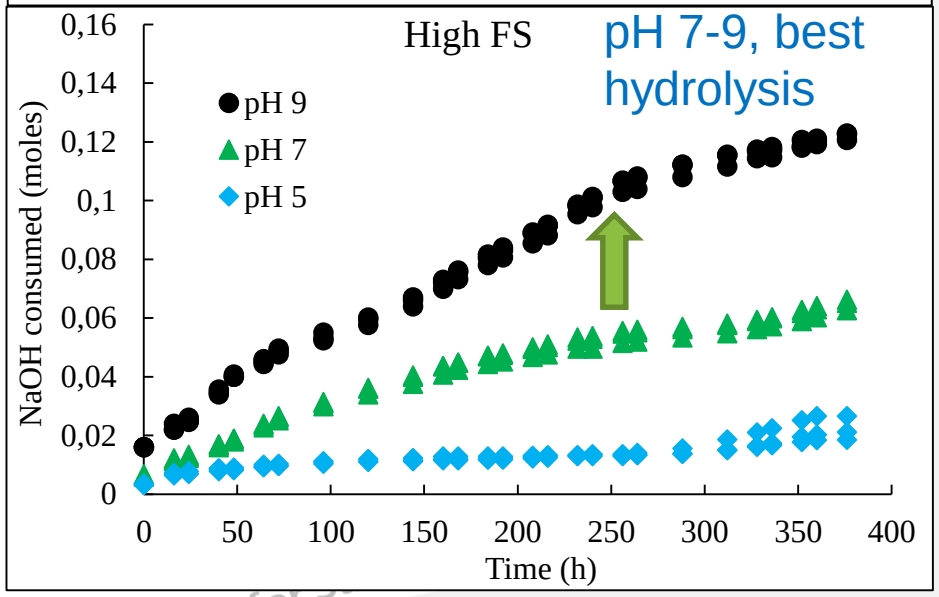
- Cellulose and lignin carbon sources

- Base addition to maintain pH
  - Almost equal hydrolysis in low and high OM bioreactors
- pH of 7-9 best for the hydrolysis
- Best hydrolysis 200-250 h, about 8-10 days, the same as in literature

Cellulose and lignin analytic, and volatile fatty acid analytic
To follow biomass hydrolysis

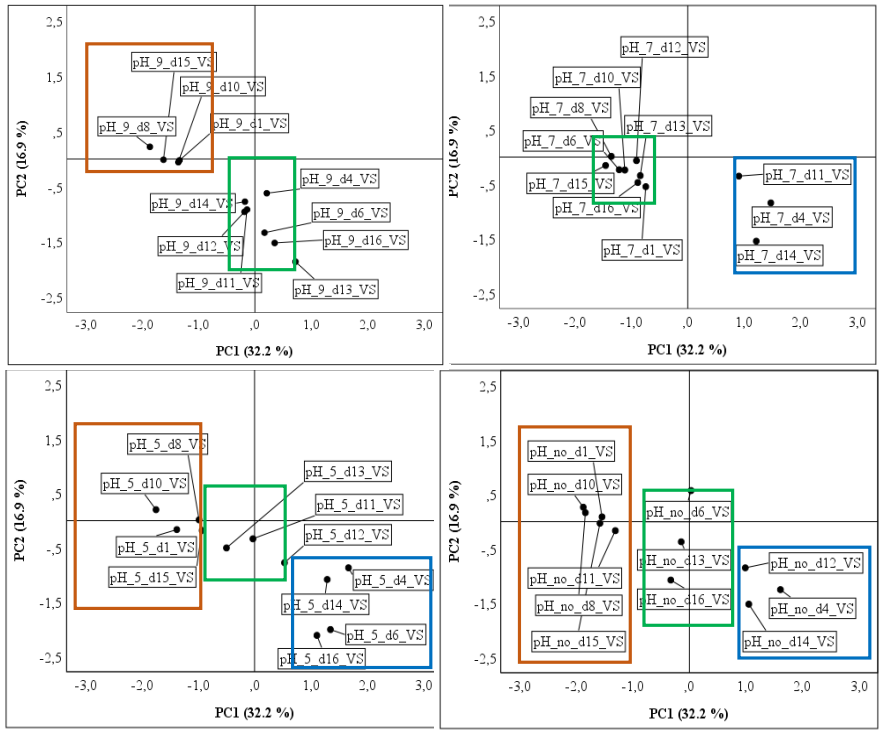
PHA analytic to follow accumulation; with simultaneous **long-chain fatty acid analysis** for microbial community evaluation





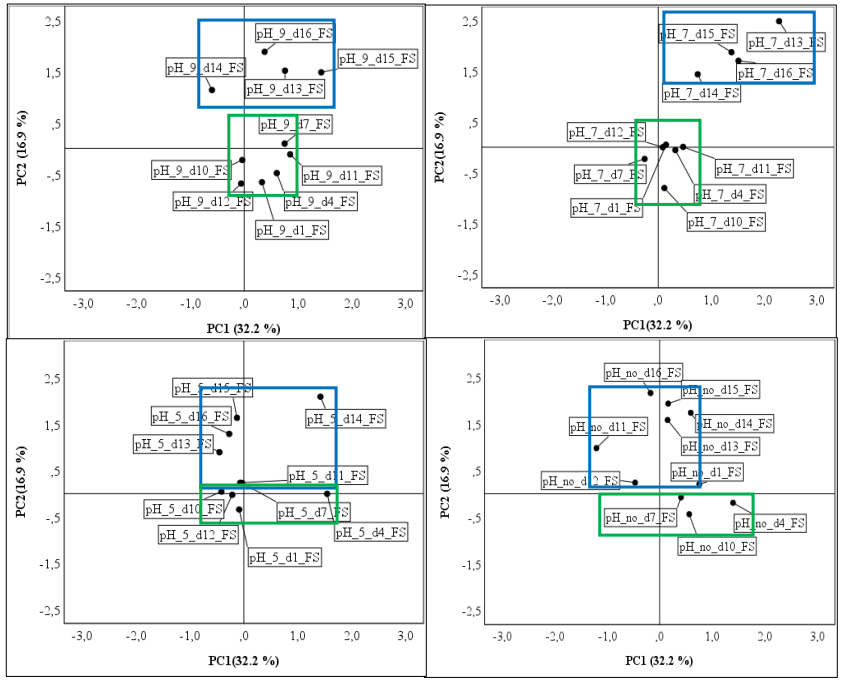
THE REGIONAL COUNCIL OF PÄIJÄT-HÄME
Leverage from the EU 2014–2020
European Union
European Regional Development Fund

Microbial community composition based on fatty acids: High OM

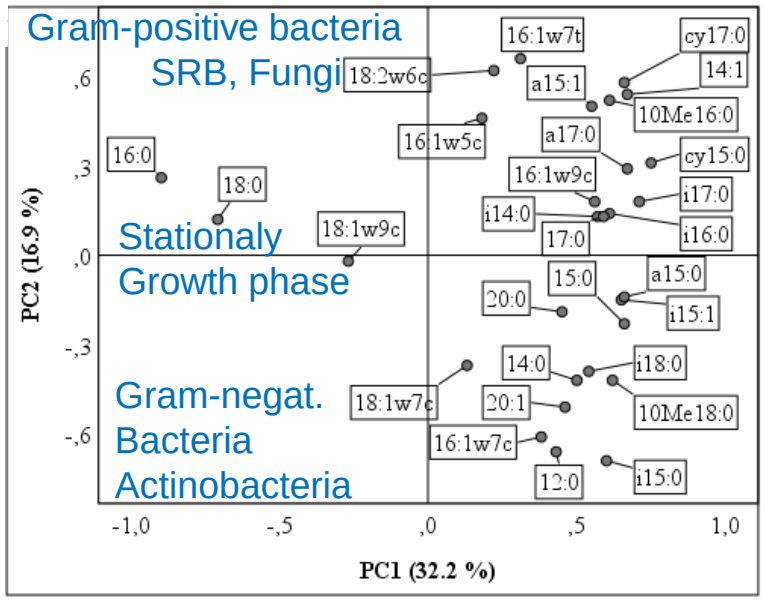


Gram-negative bacteria and **actinobacteria** appropriate for hydrolysis

Middle stage between dormant and metabolically active cells appropriate for hydrolysis

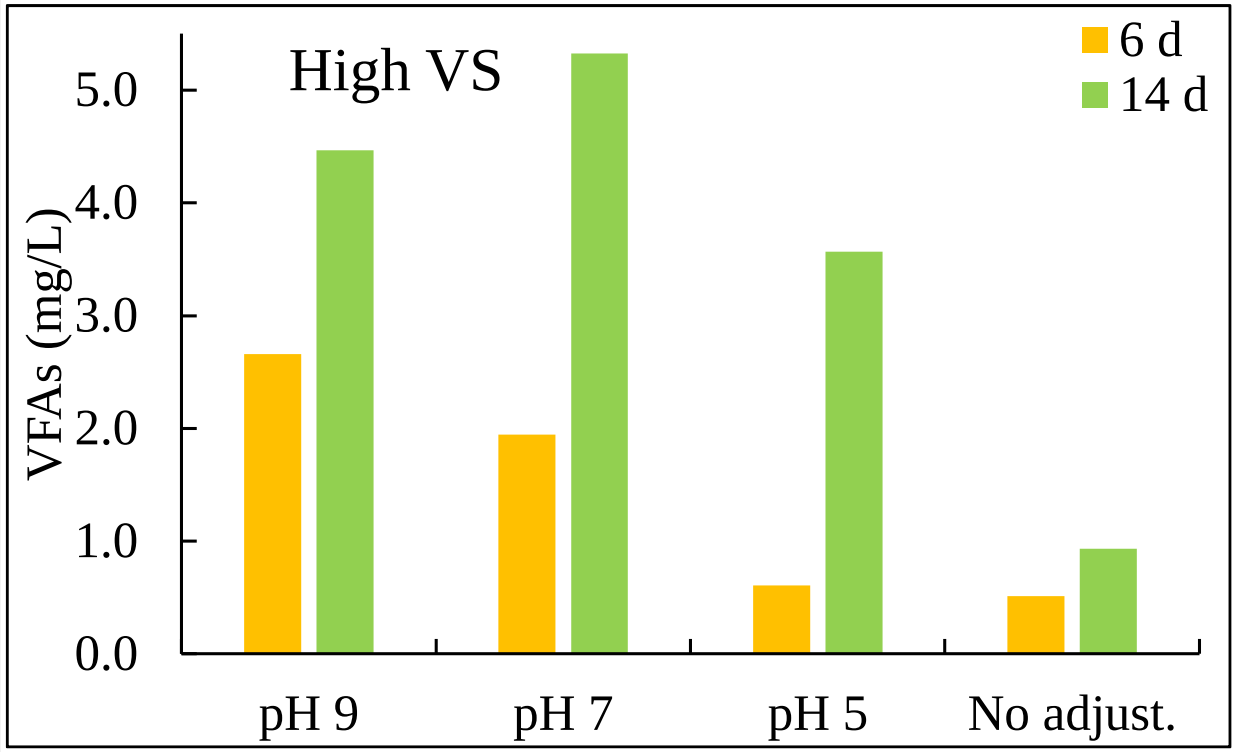


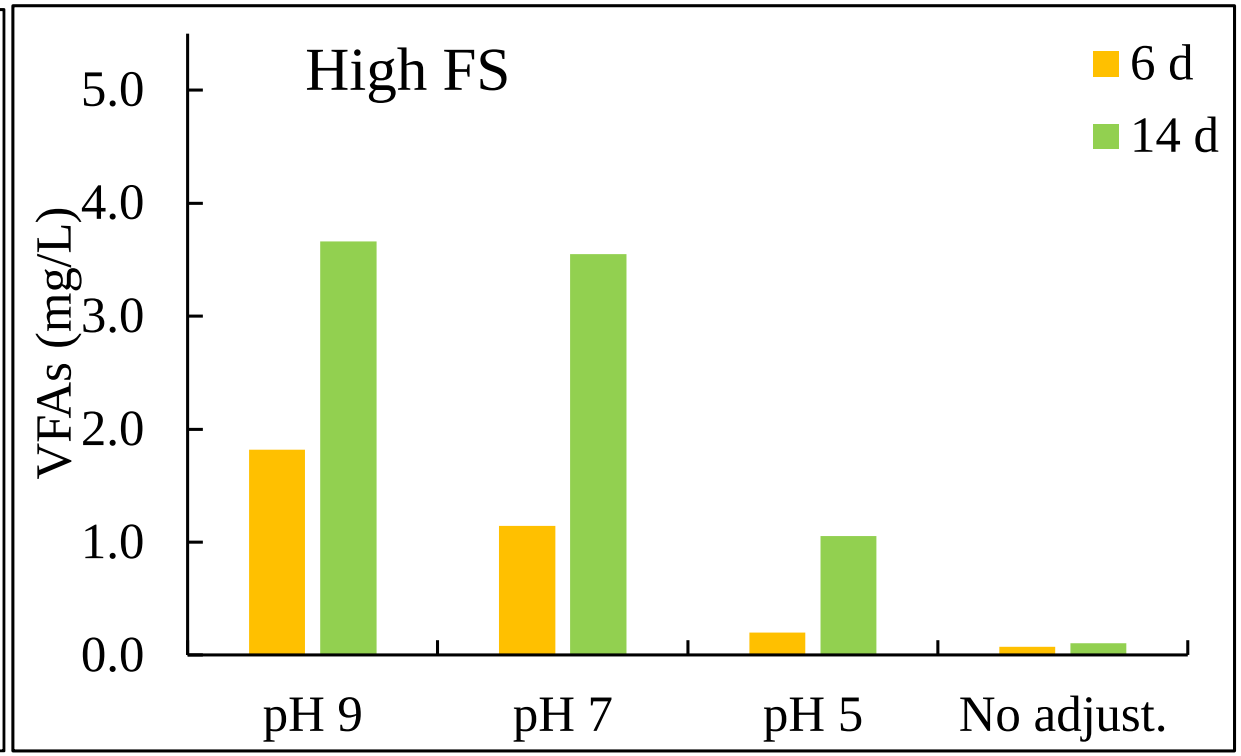
HIGH VS: When pH 7-9, microbial community is most commonly in the middle stage, down



HIGH FS: When pH 7-9, microbial community is most commonly in the middle stage, down

VFA production best at pH 7-9





Stage of research:

- The hydrolysis of different waste materials
  - Collaboration with Päijät-Häme waste treatment station, Labio Ltd and Lahti Aqua Ltd
- How waste nutrients ratios (=the quantities of different waste) can be adjusted so that they support VFA production during the hydrolysis
- Accumulation bioreactor design
- Scale up (1000 L)
- How ammonia, phosphorus and $FeSO_4$ collection can be combined with the process?
- Element enrichment (Cu, Zn)?
- Process life cycle assessment and profitability calculation of the process ongoing with LUT University (Ville Uusitalo)

UNIVERSITY OF HELSINKI

Thank you for the attention

UNIVERSITY OF HELSINKI
FACULTY OF BIOLOGICAL AND ENVIRONMENTAL SCIENCES

Programme for Sustainable Growth and Jobs

THE REGIONAL COUNCIL OF PÄIJÄT-HÄME

Leverage from the EU 2014–2020

European Union
European Regional Development Fund