



Production of PHA from residual streams

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Resource Efficient Wastewater Technology

**WOW! CLOSING EVENT – PART 2
FRIDAY SEPTEMBER 8TH – DUBLIN**

Agenda

- The WOW!-project
- Biopolymers:
Polyhydroxyalkanoates (PHA)
- Pilot-plant setup
- PHA-production from residual
streams of the food industry
- Outlook

Wastewater as a resource

Project: **WOW!**

Wider business **O**pportunities for raw materials from **W**astewater



→ Production of polyhydroxyalkanoates (**PHA**) from primary sludge

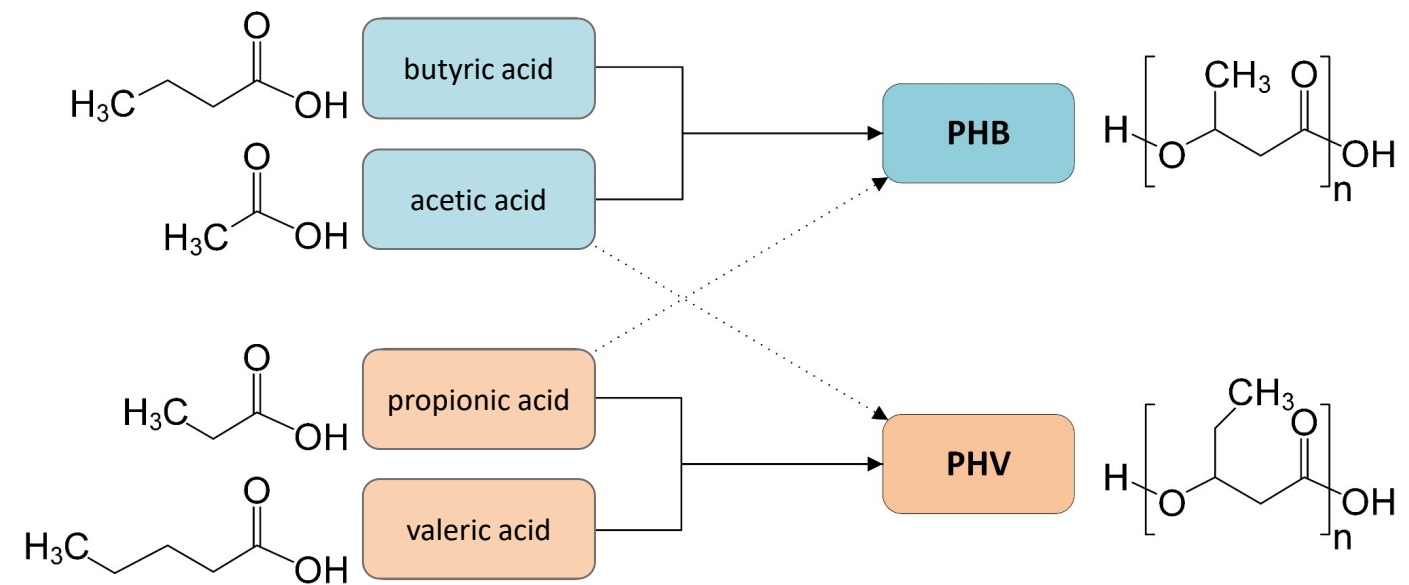
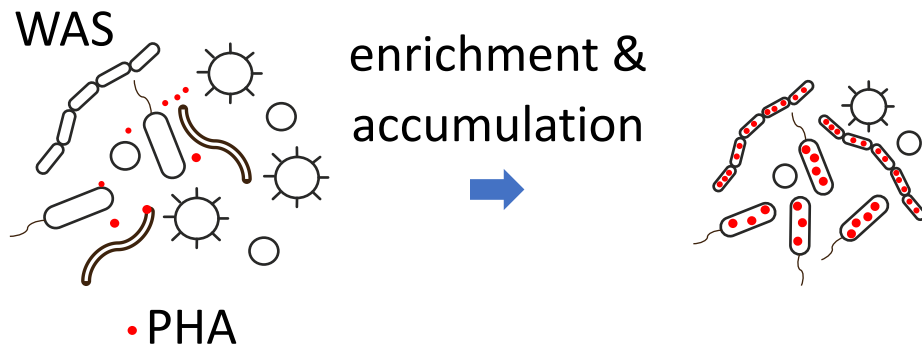
→ Results



PHA - Polyhydroxyalkanoates

- Group of biodegradable polymers
- Microbiologic storage molecule

PHA-producing bacteria are present in waste activated sludge (WAS)



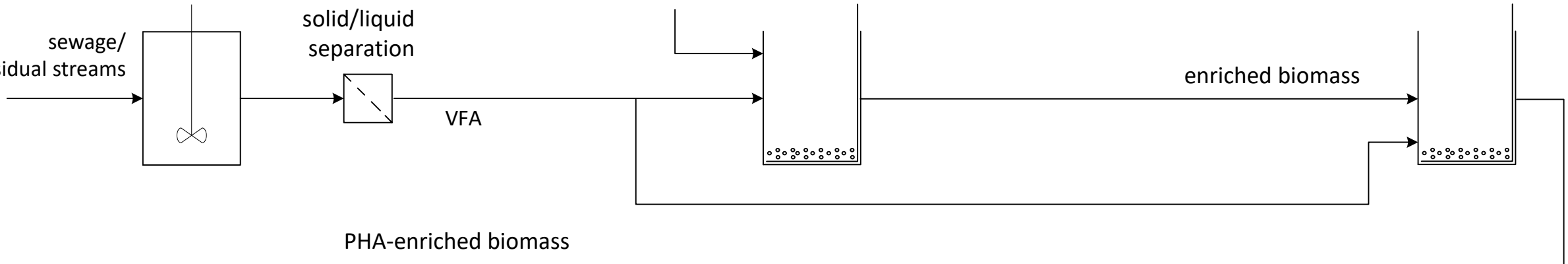
- Volatile fatty acids (VFA) from fermentation of org. residual streams as substrate for enrichment & PHA-accumulation

PHA-production – production chain

1) Acidification

2) Enrichment

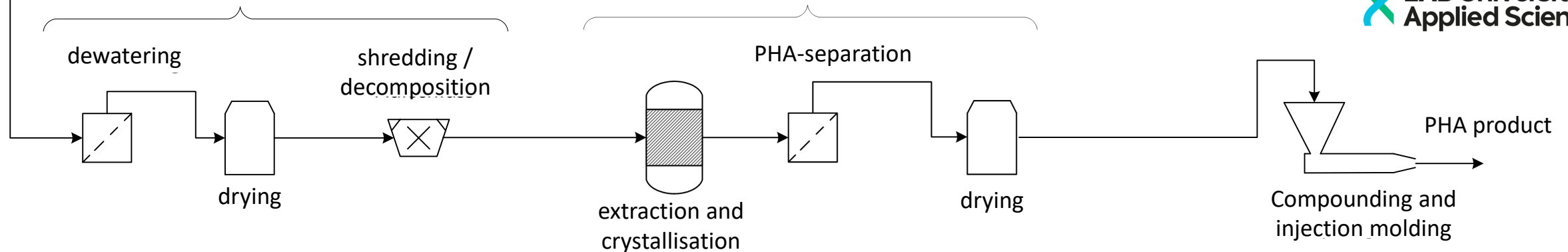
3) Accumulation



4) Down-Streaming

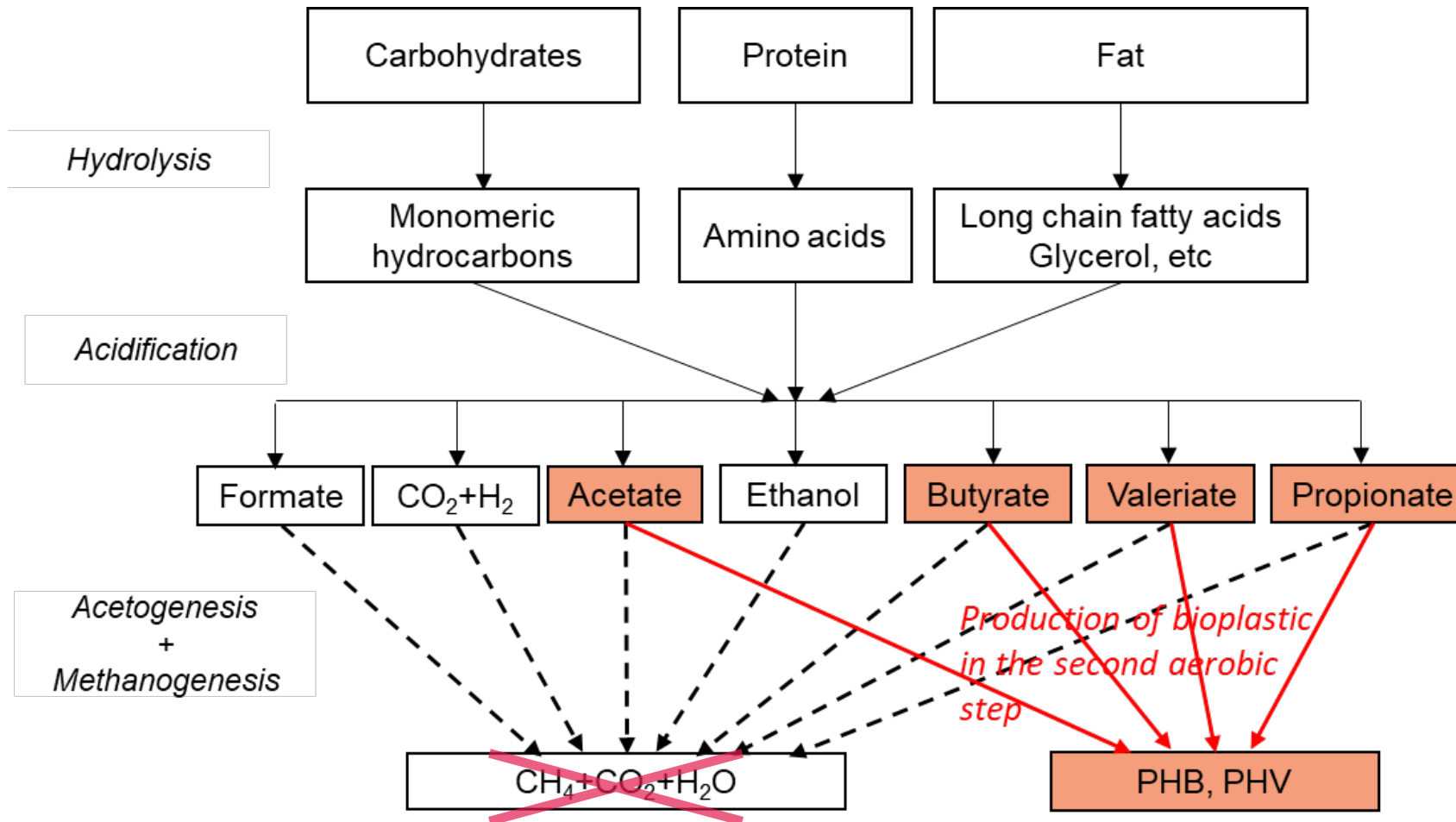
5) Extraction

6) Polymer processing



Modified from: Uhrig, T. (2023): Eignung von kommunalen und industriellen Abwasserströmen für die PHA-Produktion und Ansätze zum Up-Scaling des Prozesses. Dissertation. Schriftenreihe 10|2023, ISBN: 978-3-95974-199-6

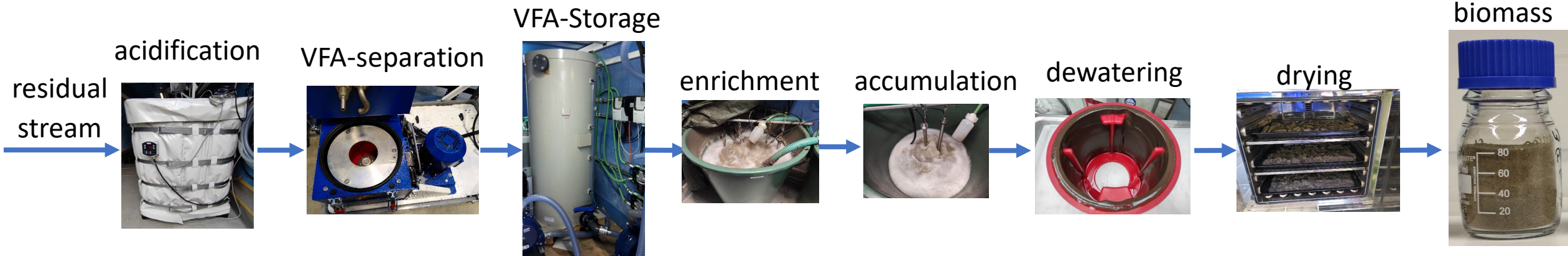
Where does the substrate for PHA-production come from?



- Anaerobic decomposition to VFA
- Methanogenesis is suppressed
- pH < 6
- Sludge age < 8d

Process of PHA production in pilot scale

- Operation: 07/2022 – 03/2023 with 2 different residual streams from the food industry
- 20 weekly acidification batches without pH control at 34 – 36°C
- 3 enrichment cycles of 2 – 4 weeks per residual stream
- 2 – 3 accumulations per week, no pH-control



Objectives of the pilot plant operation

Research questions during the production of PHA from residual streams of the food industry

- Investigating different residual streams of the food industry for PHA-production at pilot scale
- Characterisation of the VFA-rich substrates
- Investigating the influence of the substrate composition on the PHA-production process
- Characterisation of the produced PHA

Properties of the residual streams

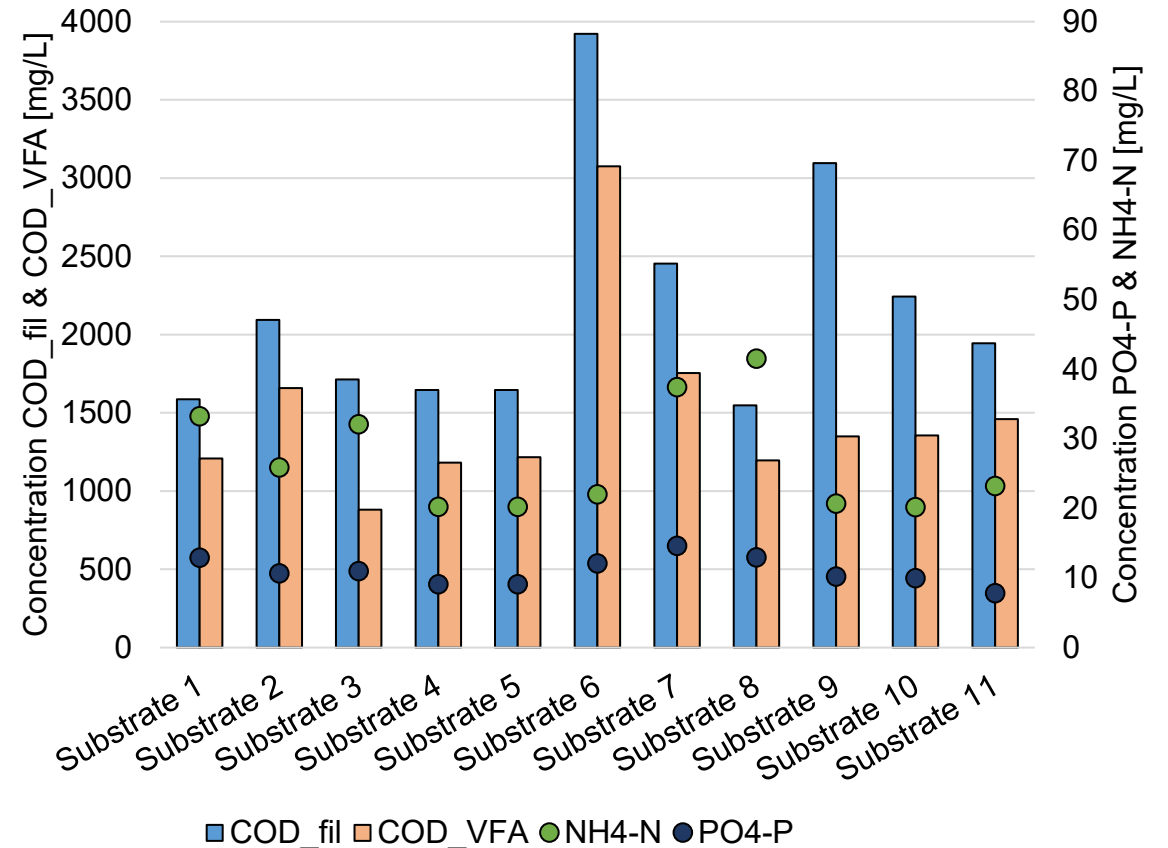
- Production all year around
 → composition of the residual stream rather stable
- Brewery has on-site treatment & a buffer tank

Produced substrate

- C:N:P-ratio*
 100 : 2.0±0.9 : 0.8±0.2 (n=11)
- COD_{VFA}/COD_{fil} : 0.69 ± 0.12



Brewery



*($COD_{VFA}:NH_4-N:PO_4-P$)

Properties of the residual streams

- Production during autumn, bottling year around
 - different residual streams
 - availability changes during the year
- Juice factory is connected to a municipal STP

Produced substrate

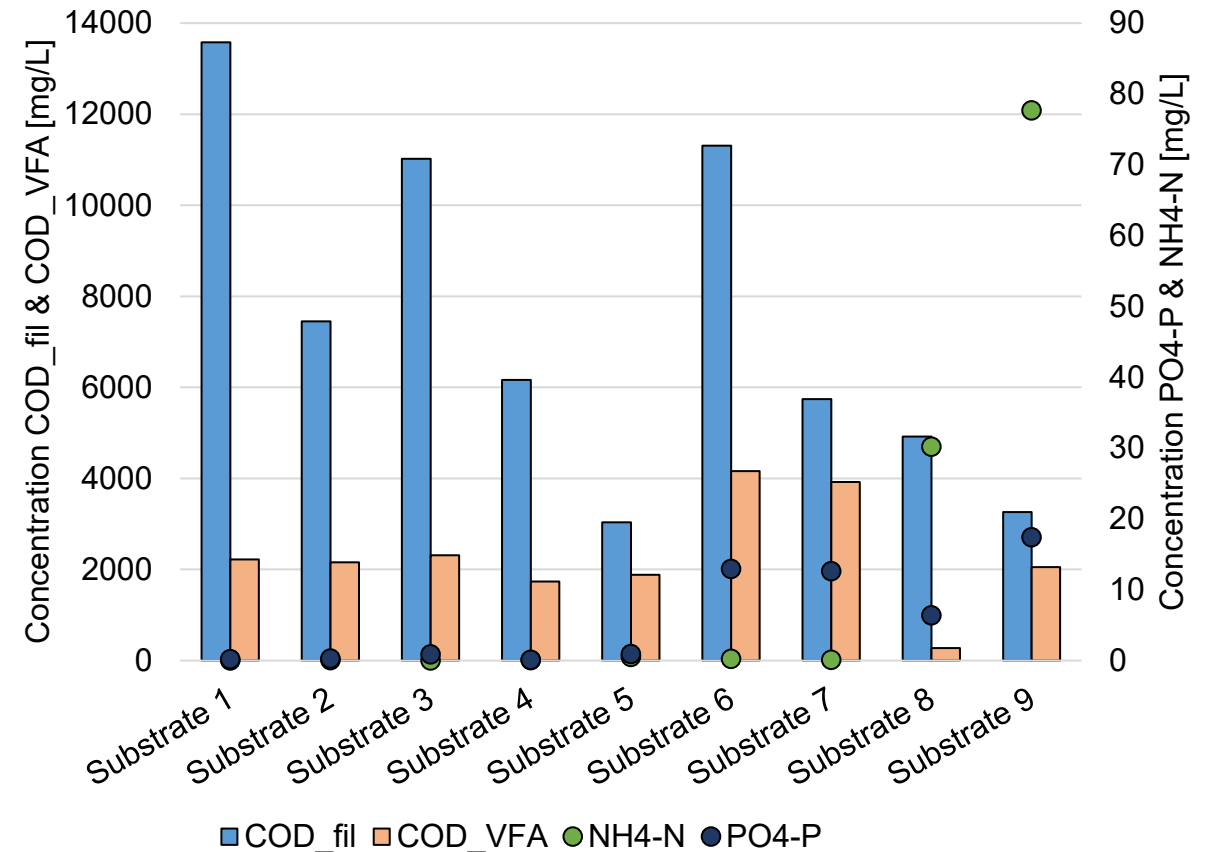
C:N:P-ratio*

100 : 0.5±1.3 : 0.2 ±0.3 (n=8)

COD_{VFA}/COD_{fil}: 0.37 ± 0.23



Fruit juice company

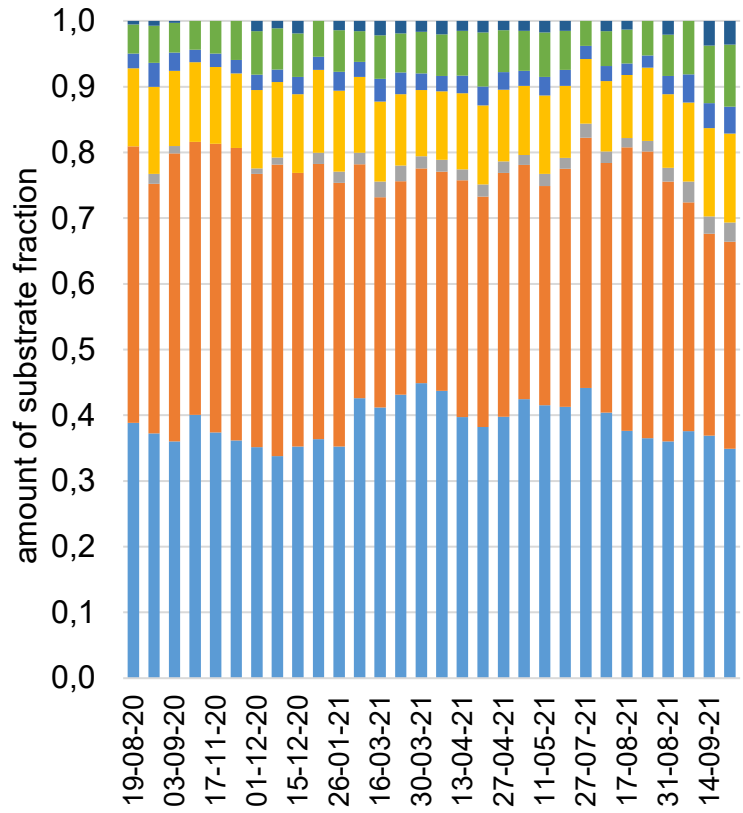


*(COD_{VFA}:NH₄-N:PO₄-P)

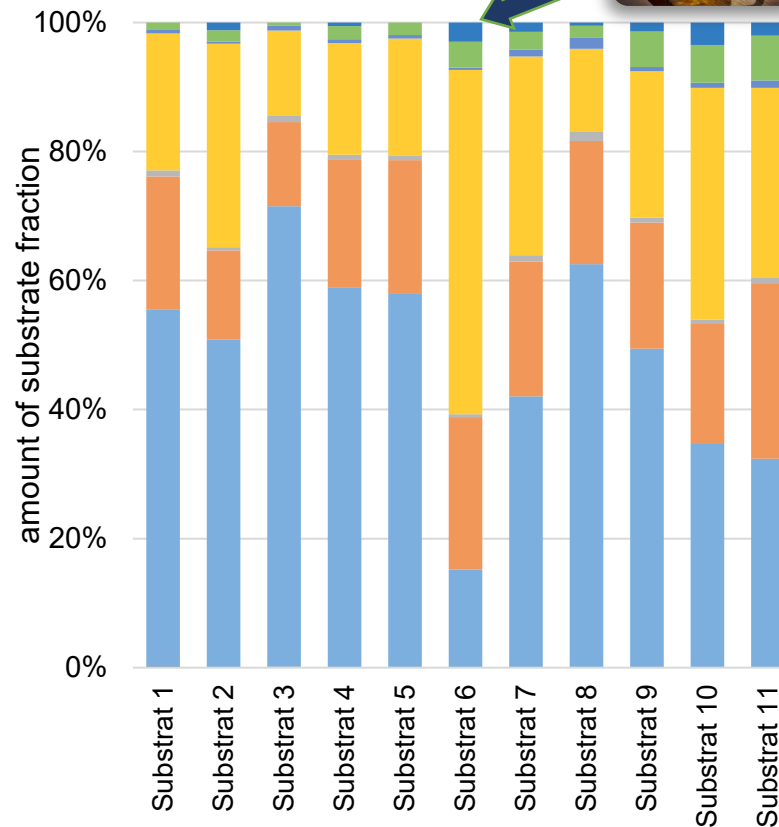
VFA-composition of different substrates



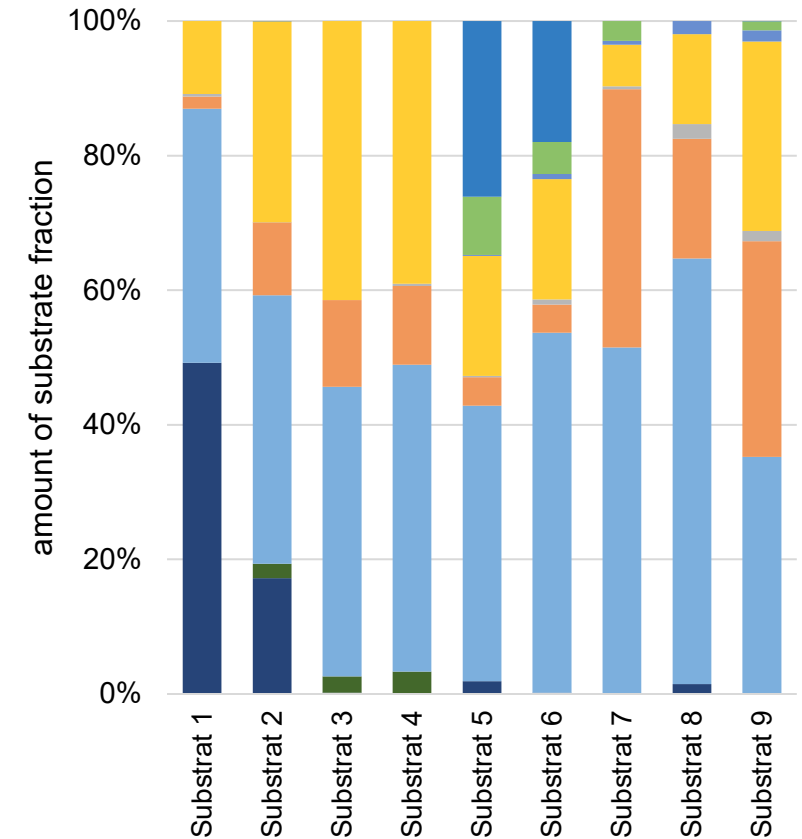
Primary sludge



Brewery's residual stream



Fruit juice company's residual stream



■ lactic acid ■ formic acid ■ acetic acid
 ■ propionic acid ■ iso-butyric acid ■ butyric acid
 ■ iso-valeric acid ■ valeric acid ■ caproic acid

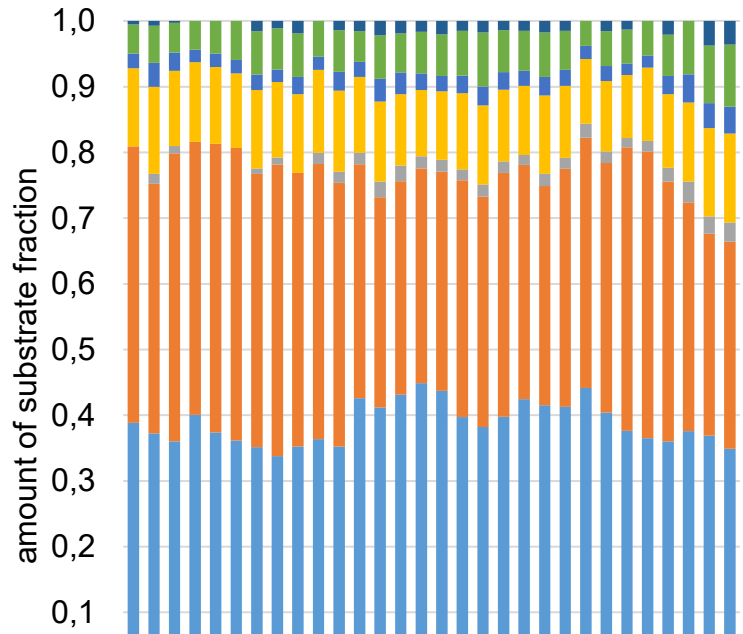
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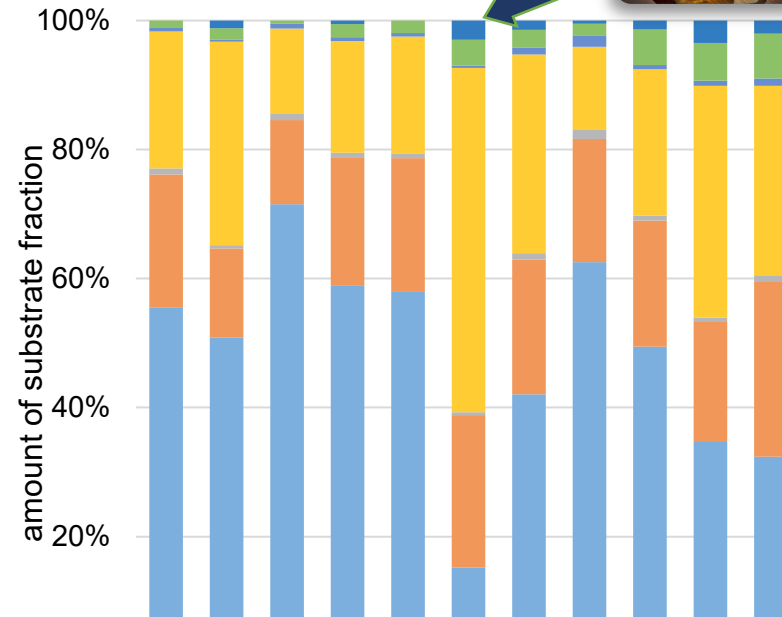
VFA-composition of different substrates



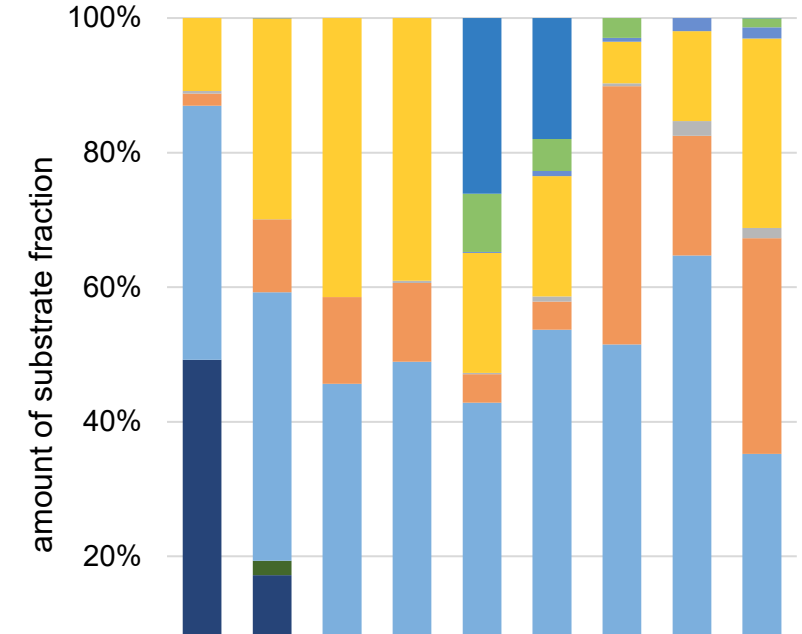
Primary sludge



Brewery's residual stream



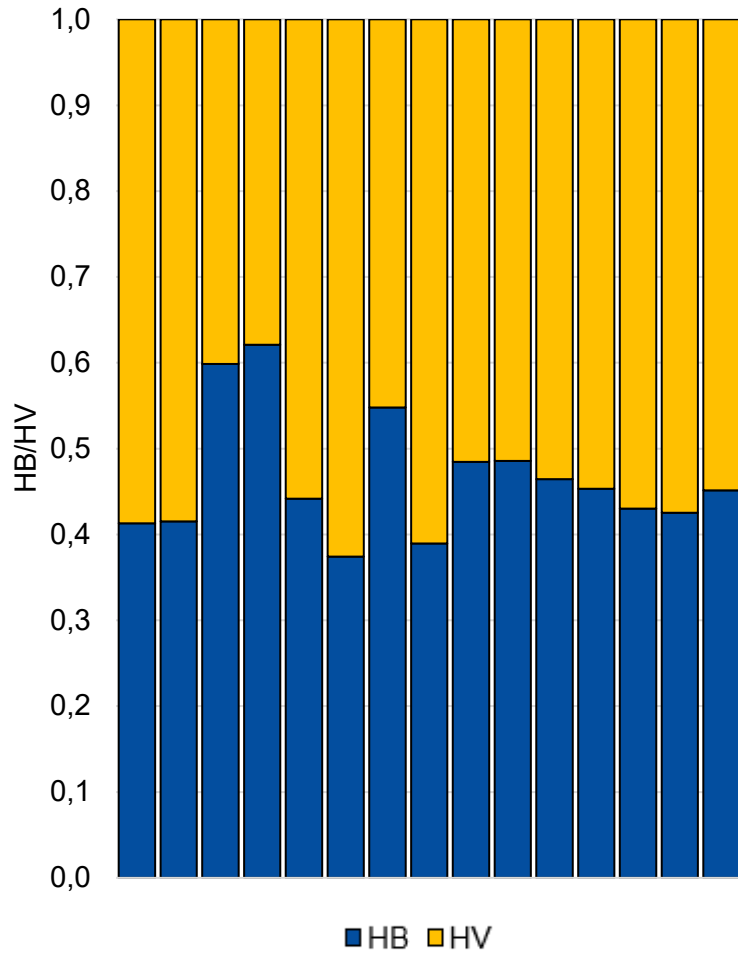
Fruit juice company's residual stream



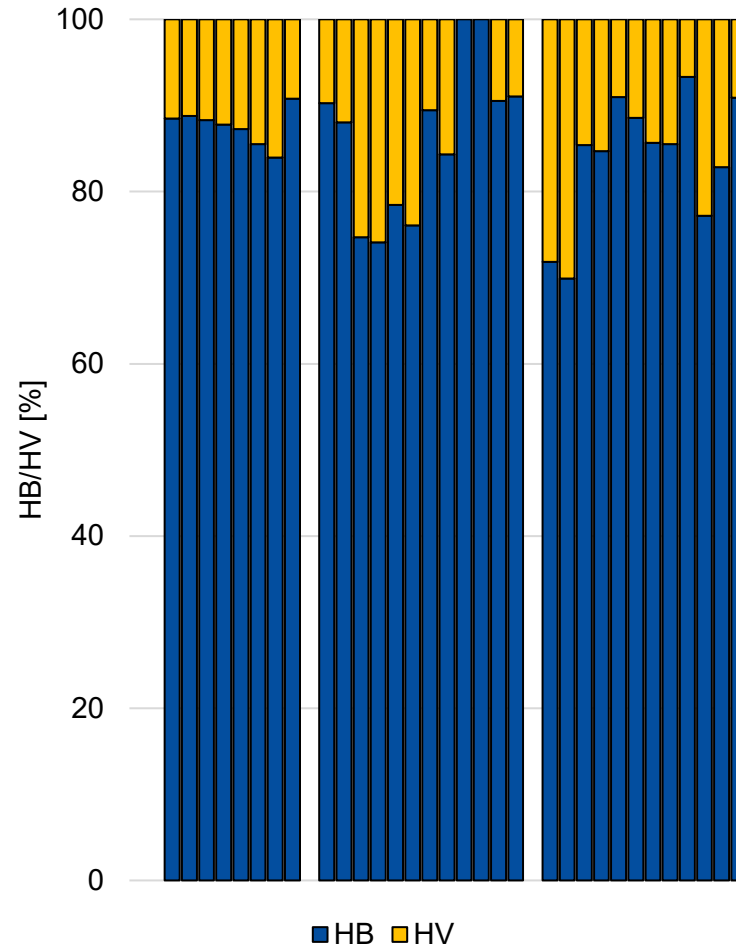
- **Different residual streams result in substrates with a different VFA composition**
- Not only differences between the substrates of the different residual streams, but **also between batches** of the same residual stream
- Primary sludge yields quite stable VFA-compositions throughout the year
- Residual stream of the **fruit juice company** resulted in **higher COD_{VFA}** , but **lower ratio of COD_{VFA}/COD_{fil}**

PHA-composition of different substrates

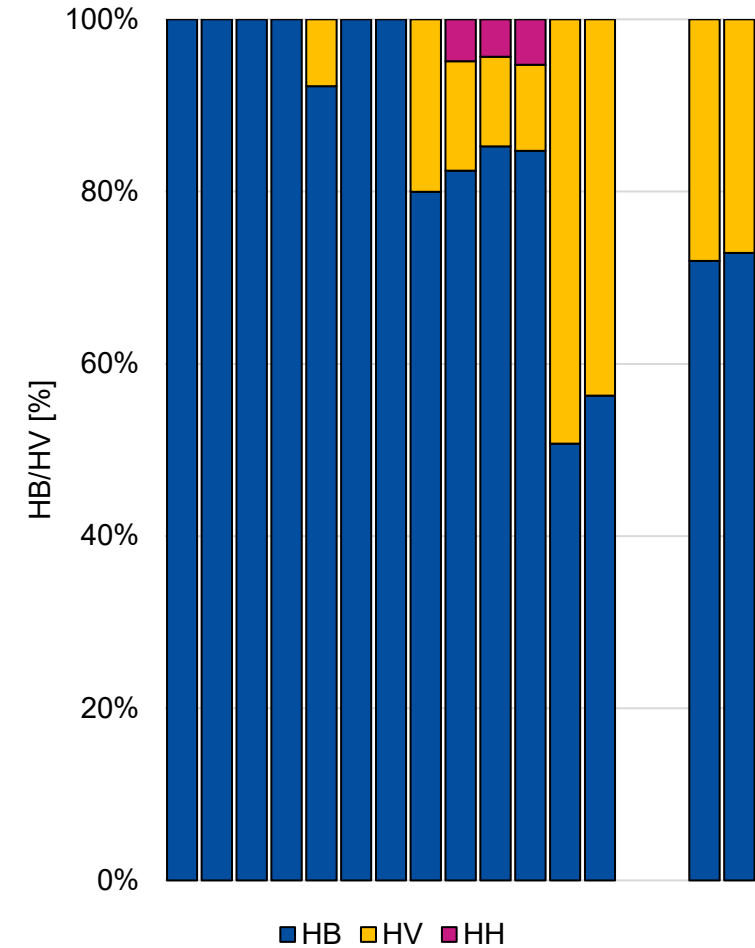
Primary sludge



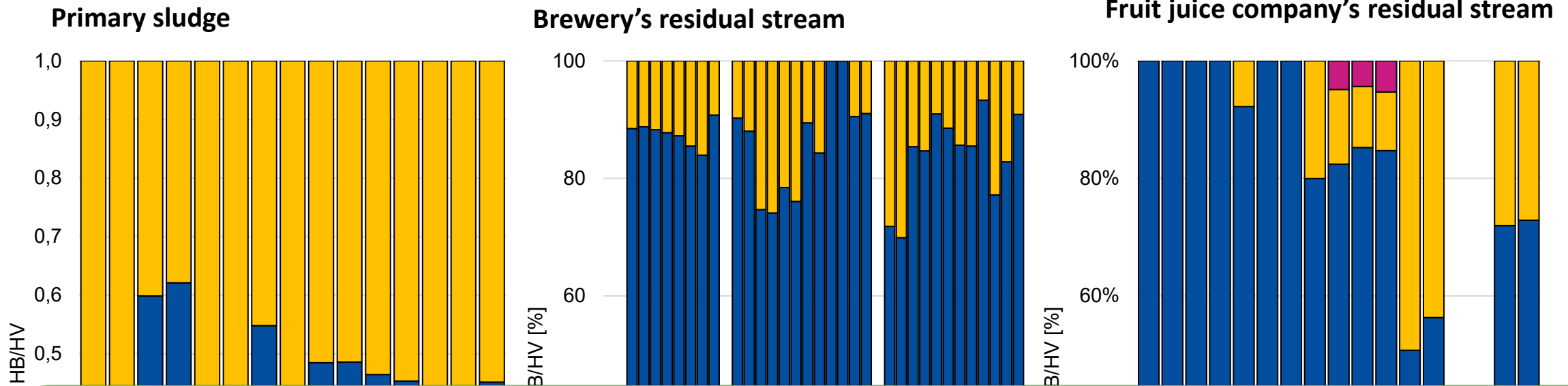
Brewery's residual stream



Fruit juice company's residual stream



PHA-composition of different substrates



- **PHA mainly consists of HB for both residual streams**
- **Different VFA composition causes differences in the PHA composition**
- Substrate rich in **caproic acid** causes **hydroxyhexanoate (HH)** production
- **PHA** produced from **brewery** have a **more stable composition** compared to the residual stream of the fruit juice company
- **Future objective:** adjust HB/HV composition to the needs of the plastic industry

Take-home message & outlook I/II

Municipal sewage treatment plant

- Stable VFA and PHA composition throughout the year, also during winter
- Aid flows are not necessary for the process
- Some questions still remain:
 - Impact of the non-VFA-COD on enrichment and accumulation
 - Strategies for a stabilisation of the TS-concentration

Industrial wastewater

- Substrate composition fluctuates depending on the residual stream and process
- fruit juice wastewater achieved a PHA-content of up to > 60% of the org. dry matter
- Depending on the residual stream, the addition of nutrients is essential for the enrichment process

Take-home message & outlook II/II

Produced PHA and possible impact on the product properties

- new application possibilities due to the synthesis of co-polymers
 - PHB/PHV from primary sludge
 - PHB/PHV/PHH from industrial sewage
- Impact of the PHA-composition on the product quality is currently investigated
- High potential for substituting PE

Research questions and challenges for the upscaling

- Impact of the biocenosis
- Under which circumstances is an enrichment necessary
- Predictability of the PHA-composition and stabilisation of the different processes
- Downstream processing and product properties (including biodegradability)

Interreg



EUROPEAN UNION

North-West Europe

WOW!

European Regional Development Fund

Thank you!



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