Food waste and waste activated sludge co-fermentation to enhance VFA production

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Acidogenic fermentation

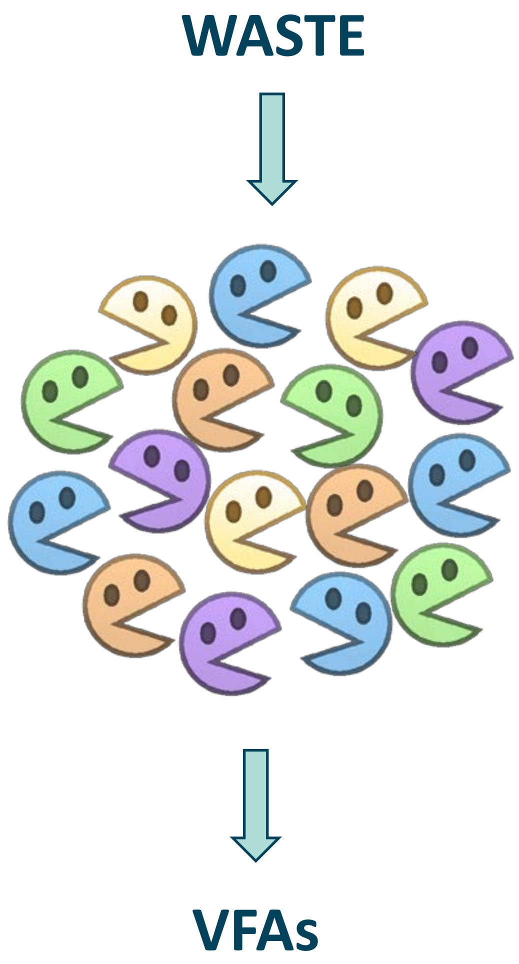
- From end-of-pipe waste treatments to waste integrated resource recovery schemes.

WWTP/ MBT ⟹ **BIOREFINERIES**

- Acidogenic fermentation is a key unit

Organic matter ⟹ Easily assimilable compounds like **VFAs**

- VFAs are useful to:
  - Biopolymers production (PHA)
  - Biological nutrients removal (i.e. N, P and S)
  - Chain elongation



Waste Activated Sludge (WAS) fermentation

- WAS is the main substrate of WWTP.
- WAS fermentation is limited by low fermentation yields.

- Pre-treatments → Capital and operational costs $

How to overcome it?

Co-fermentation advantages

- Co-fermentation achieves an improvement of fermentation performance by:

1. Higher organic matter content
2. Improved buffer capacity
3. Balance of nutrients and moisture
4. Dilution of inhibitory and toxic compounds
5. Diversification of hydrolytic-fermentative bacteria

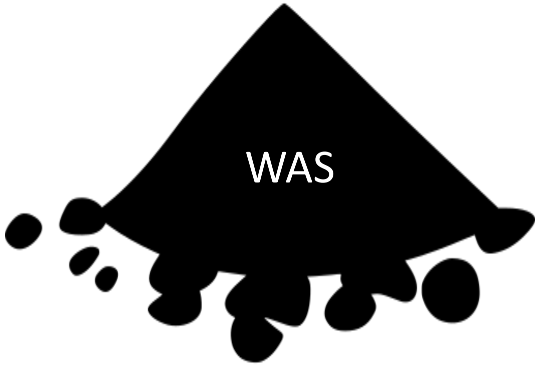
WAS/FW co-fermentation

- Food Waste (FW) is the most researched co-substrate for WAS co-fermentation.

  - Availability
  - High fermentation yield

- Co-fermentation literature does not clearly explain:

  - Impact of the co-fermentation mixture on VFA yield and profile.
  - Importance of WAS alkalinity on the pH of fermentation liquor.
  - Impact of pre-treatments on co-fermentation performance.
  - How co-fermentation behaves when WAS, instead of FW, is the main substrate.



Aim of this study

- To investigate the performance of WAS/FW co-fermentation under different experimental conditions to understand the benefits and constraints of this approach.

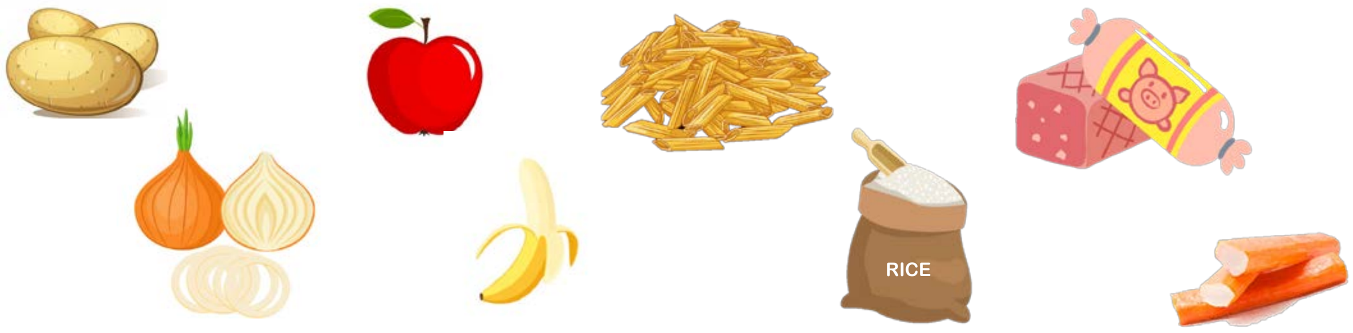
  - Impact of WAS/FW mixture ratio.

  - Impact of pH on co-fermentation performance.

  - Feasibility of WAS auto-hydrolysis pre-treatment to improve fermentation yields.

Substrates

- Thickened WAS from WWTP in Barcelona
- Synthetic FW with reported real composition [1] [2] [3]
  - 30% w/w of vegetables
  - 30% w/w of fruits
  - 20% w/w of carbohydrates
  - 10% w/w of meat
  - 10% w/w of fish and seafood



- Ingredients available in supermarket all the year round.

[1] Braguglia, C.M et al.. (2018). Anaerobic bioconversion of food waste into energy: a critical review. *Bioresource Technology 248*, 37–56

[2] Capson-Tojo, G. et al. (2016). Food waste valorization via anaerobic processes: a review. *Reviews in Environmental Science and Bio/Technology*, *15*(3), 499-547.

[3] Hassan, G. K. et al. (2019). A novel method for increasing biohydrogen production from food waste using electrodialysis. *International Journal of Hydrogen Energy, 44*(29), 14715-14720.

Fermentation batch assays

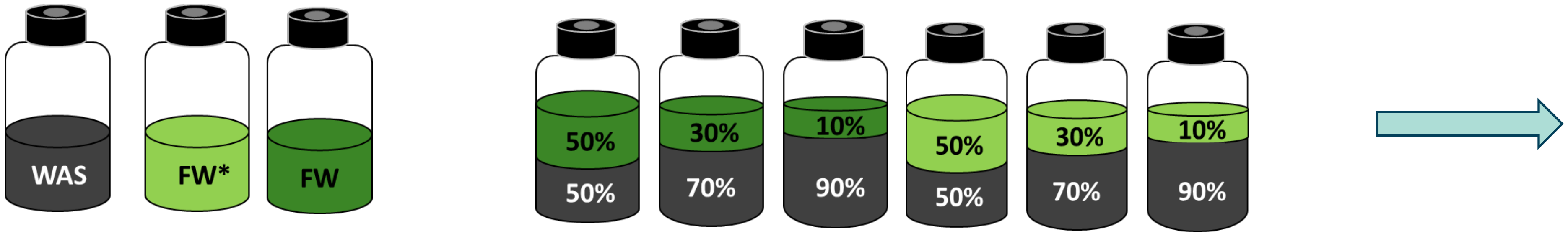
- Anaerobic conditions flushing N_2 for 2 min
- Mesophilic conditions (35 ºC)
- Without inoculum addition
- Non destructive assays

→ TS, VS, pH, VFAs, lactic acid, $N\text{-}NH_4^+$

Fermentation batch assays

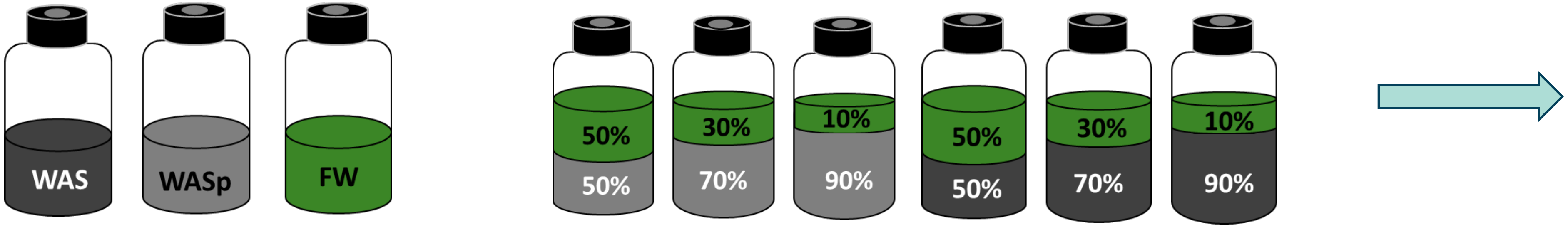
1. Impact of WAS/FW **mixture** on co-fermentation performance

2. Impact of FW **buffer capacity** on co-fermentation performance



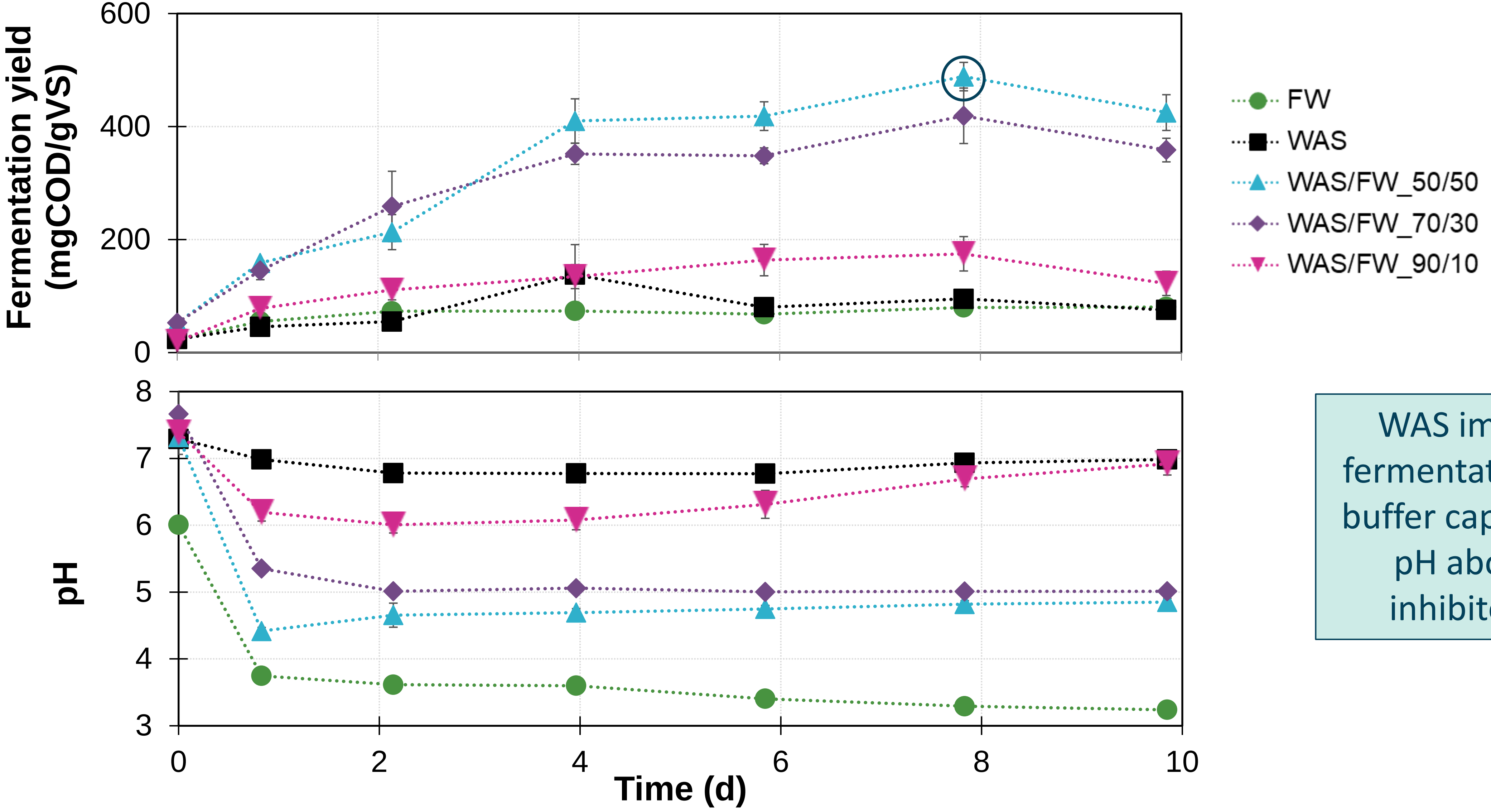
FW* is referred to FW with additional alkalinity (30 g $NaHCO_3/kg_{ww}$)

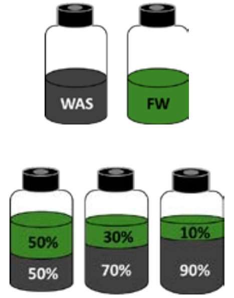
3. Impact of WAS **auto-hydrolysis** on co-fermentation performance



WASp is referred to WAS autohydrolysis pre-treatment (55 ^{o}C during 2h 30 min)

1. Impact of WAS/FW mixture on co-fermentation performance

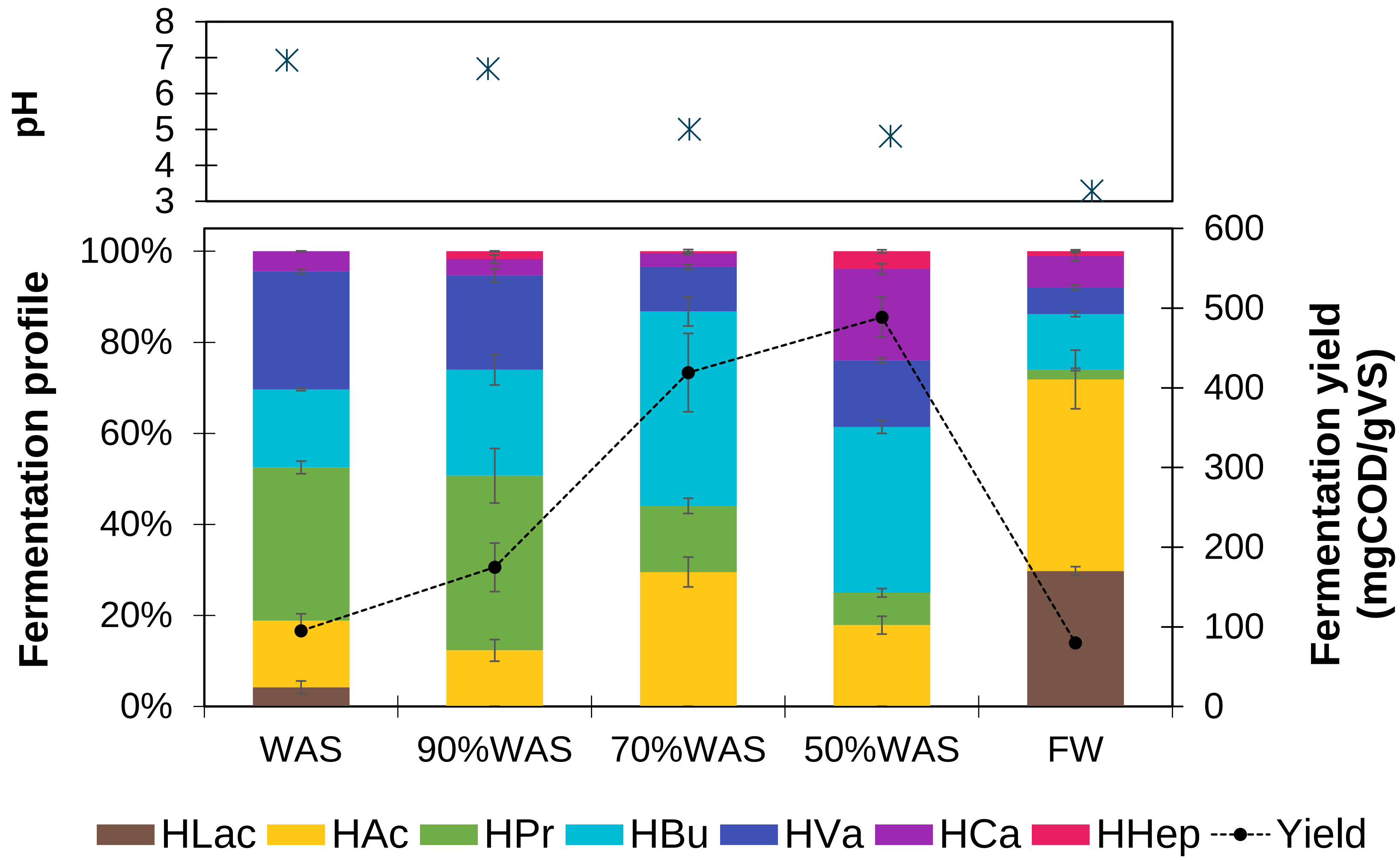




WAS improved FW fermentation providing buffer capacity keeping pH above severe inhibitory values.

1. Impact of WAS/FW mixture on co-fermentation performance

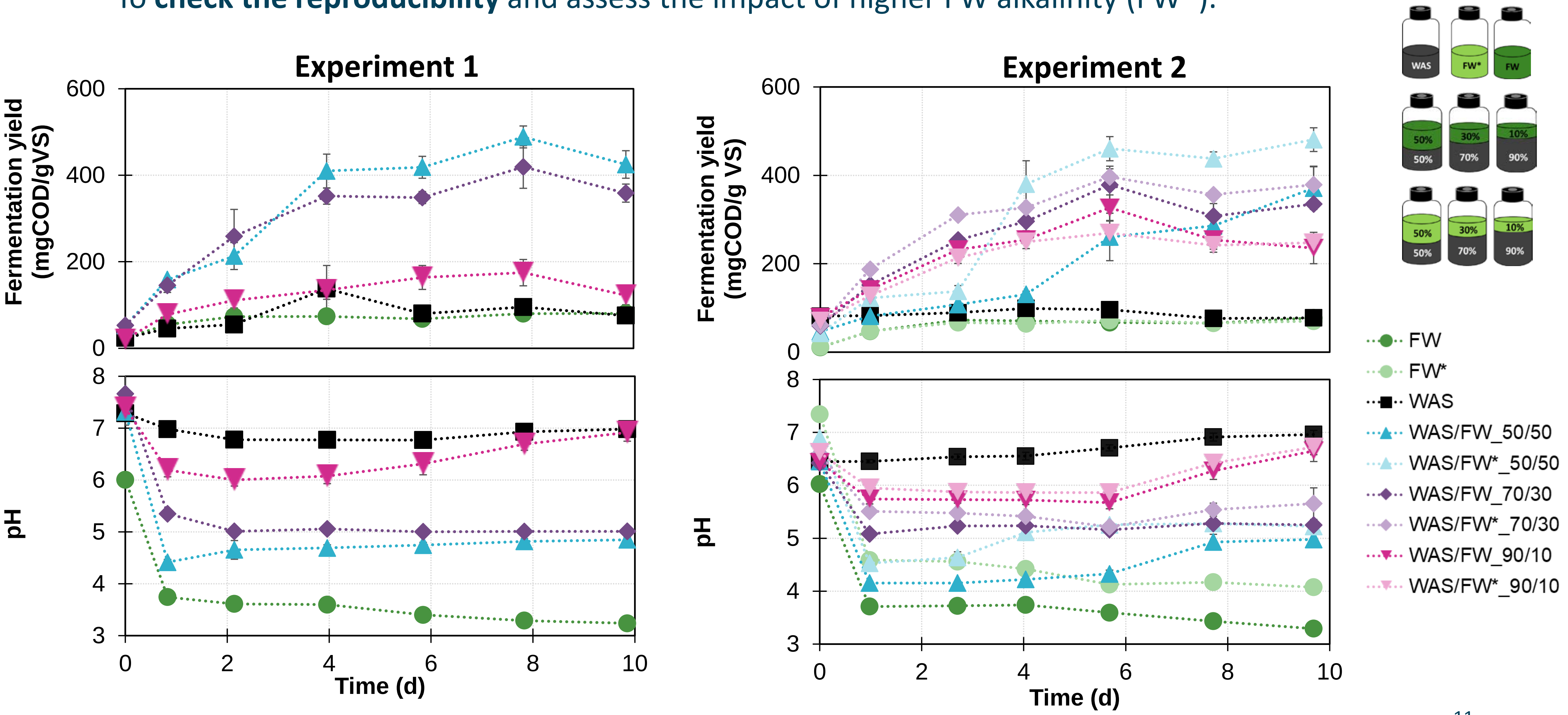
- WAS: HPr , Hva and HBu
- FW: HAc and HLac
- Dominance of HBu in 70% and 50% WAS.
- 90% WAS closer than mono-fermentation.



The profile is controlled by composition and pH.

2. Impact of FW buffer capacity on co-fermentation performance

To **check the reproducibility** and assess the impact of higher FW alkalinity (FW*).



2. Impact of FW buffer capacity on co-fermentation performance

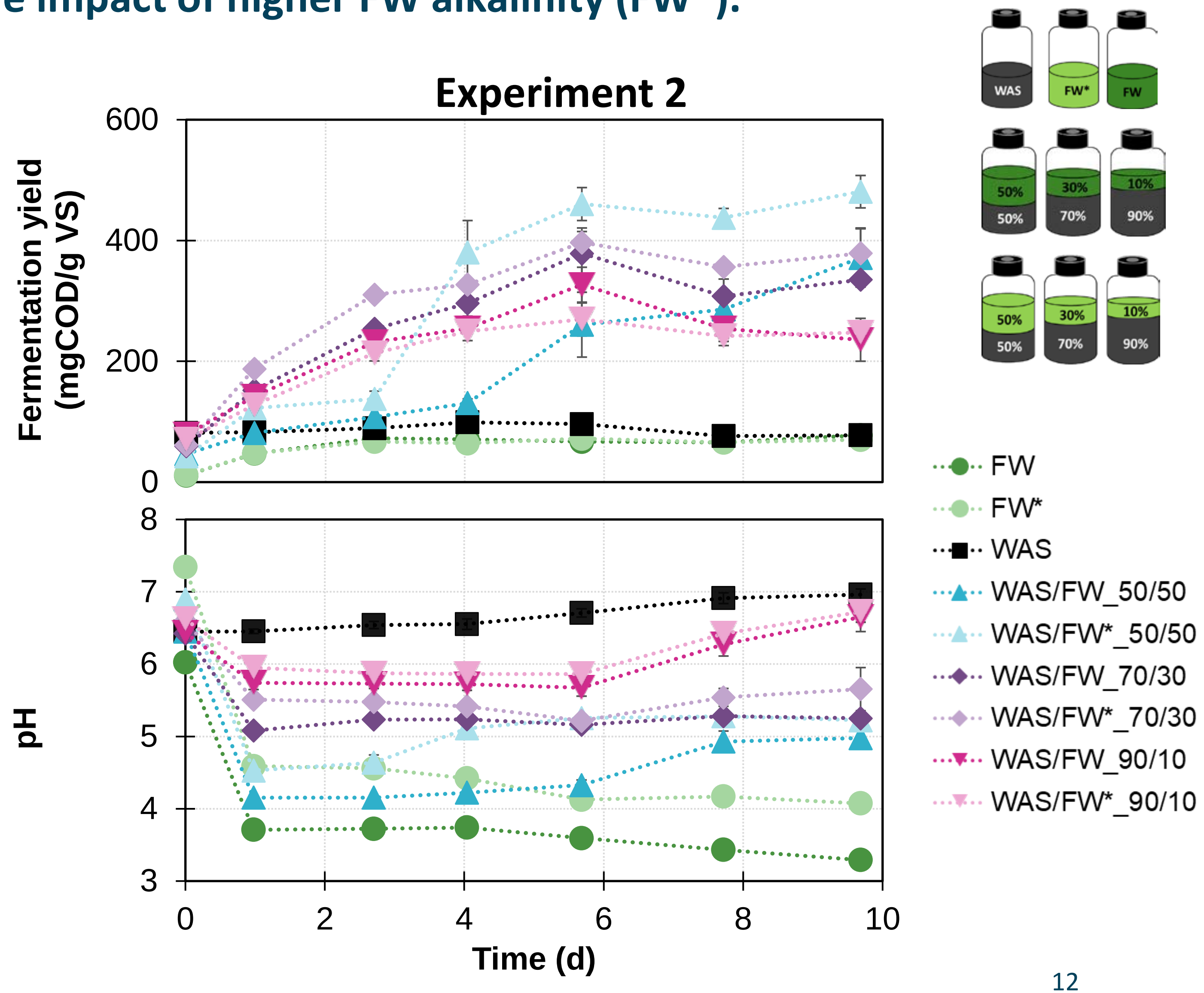
To check the reproducibility and **assess the impact of higher FW alkalinity (FW*).**

- Alkalinity addition not enough in mixture 70% and 90% WAS.
- In mixture 50% have remarkably effect.

⇩

pH to 4.2 at 5.1

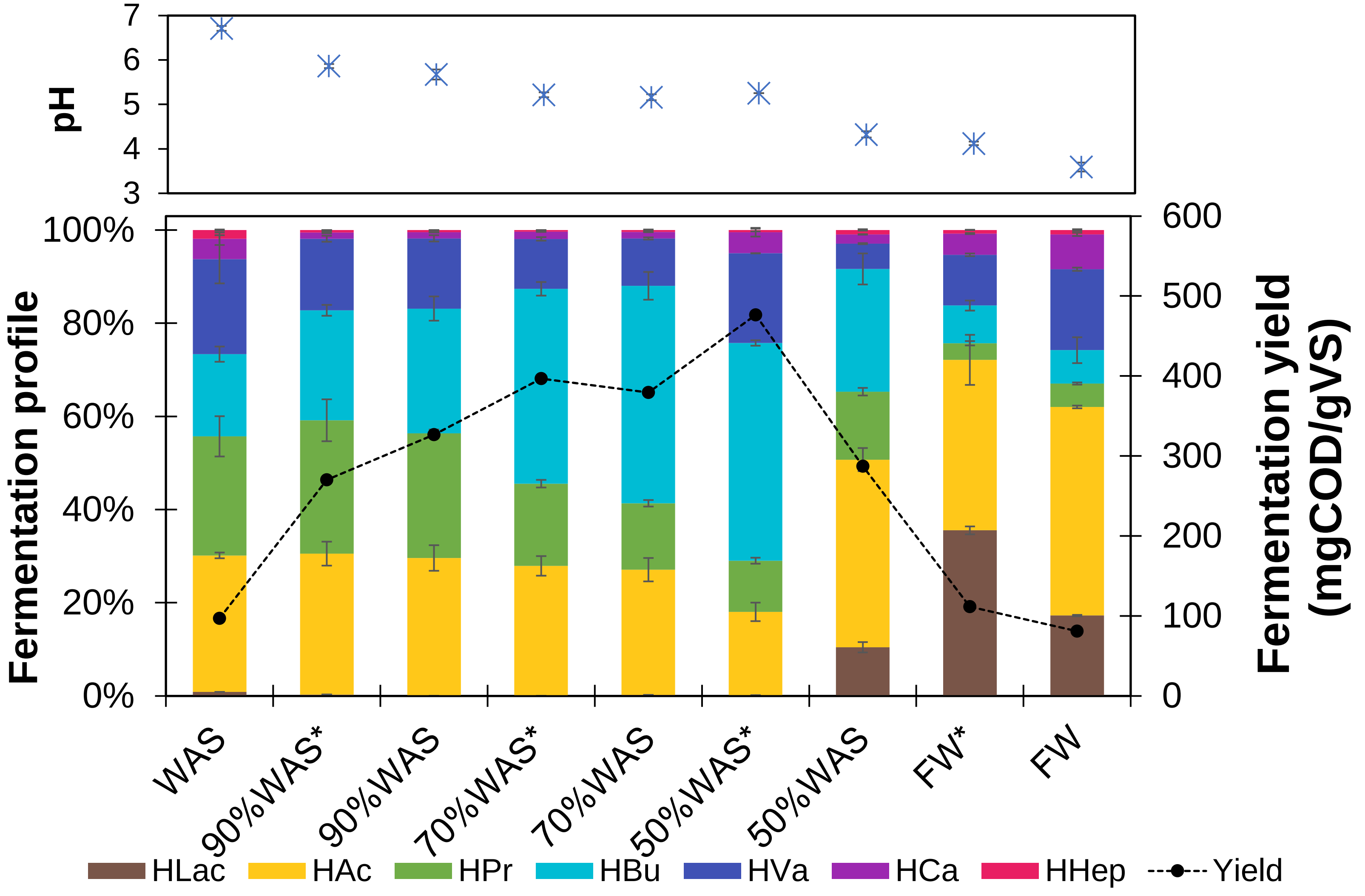
The amount of FW in co-fermentation should be limited to keep the pH above 5.0.



2. Impact of FW buffer capacity on co-fermentation performance

Butyric acid was enriched as FW proportion was increased in the mixture with concomitant pH decreased.

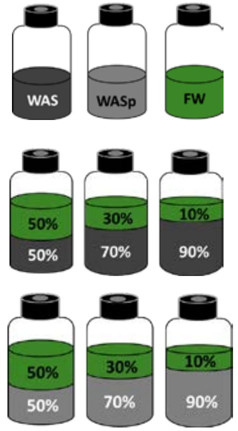
Propionic acid prevailed at higher WAS proportions and neutral pH.

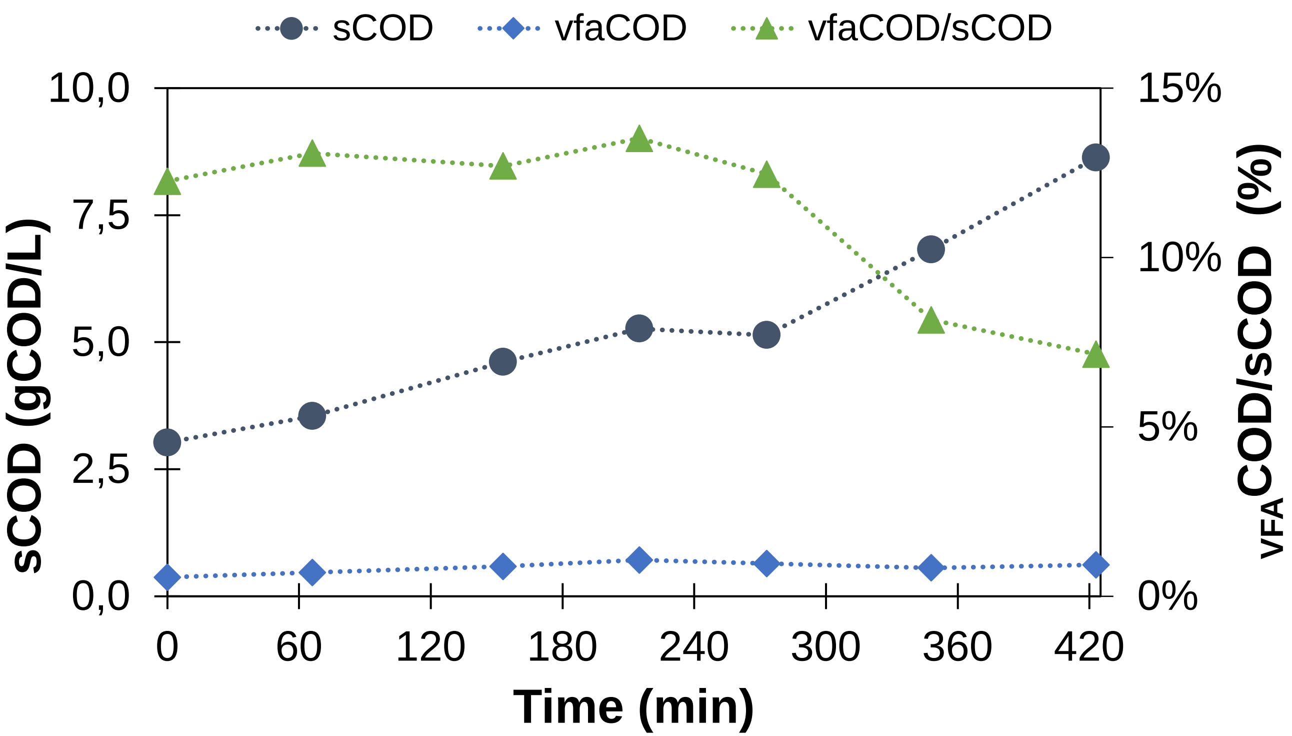


3. Impact of WAS auto-hydrolysis on co-fermentation performance

- **Autohydrolysis pre-treatment** at 55 ºC was carried out in WAS.

- During the pre-treatment of 2h30min the sCOD increased from 3.0 gCOD/L to 8.6 gCOD/L.

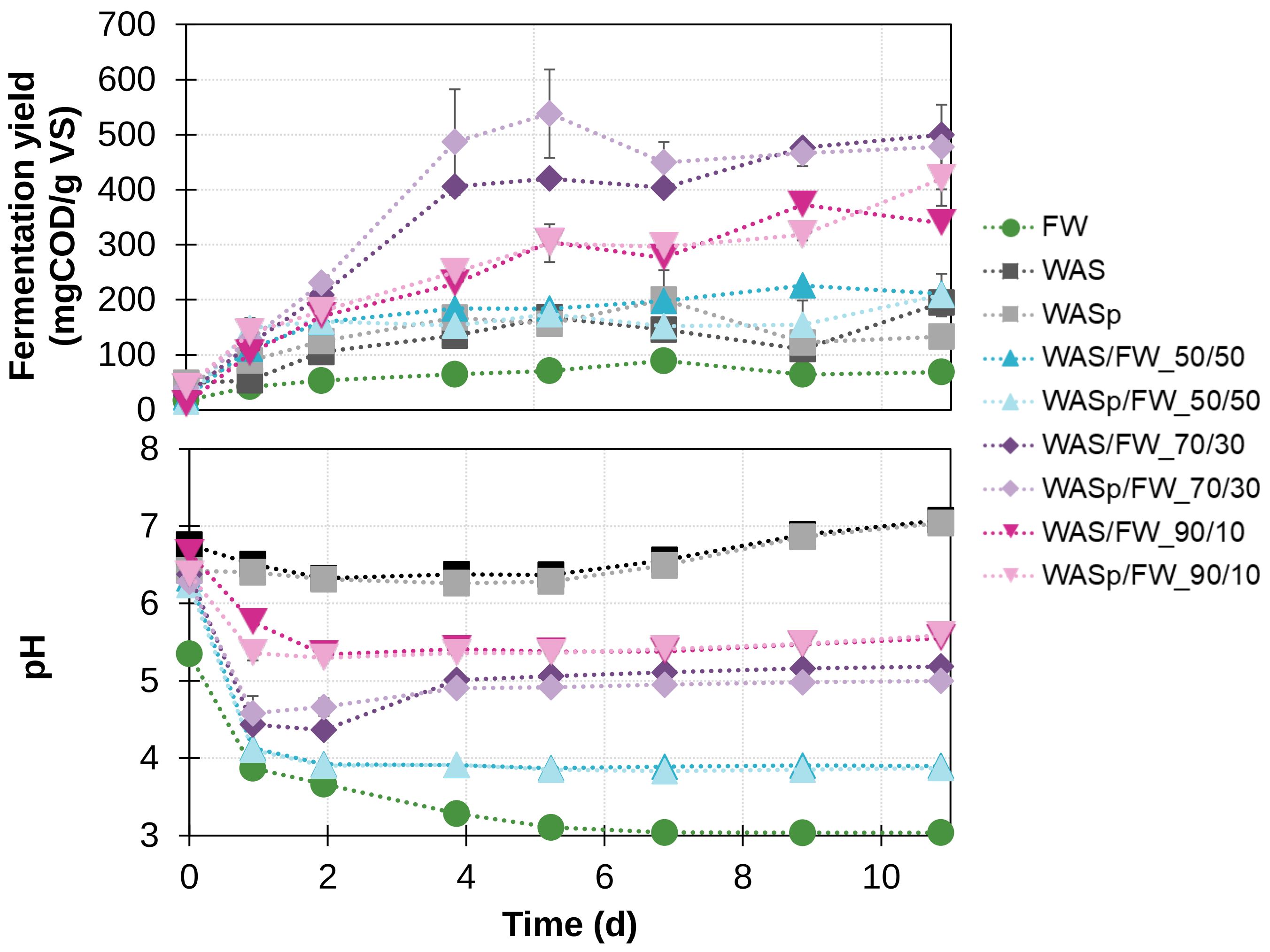


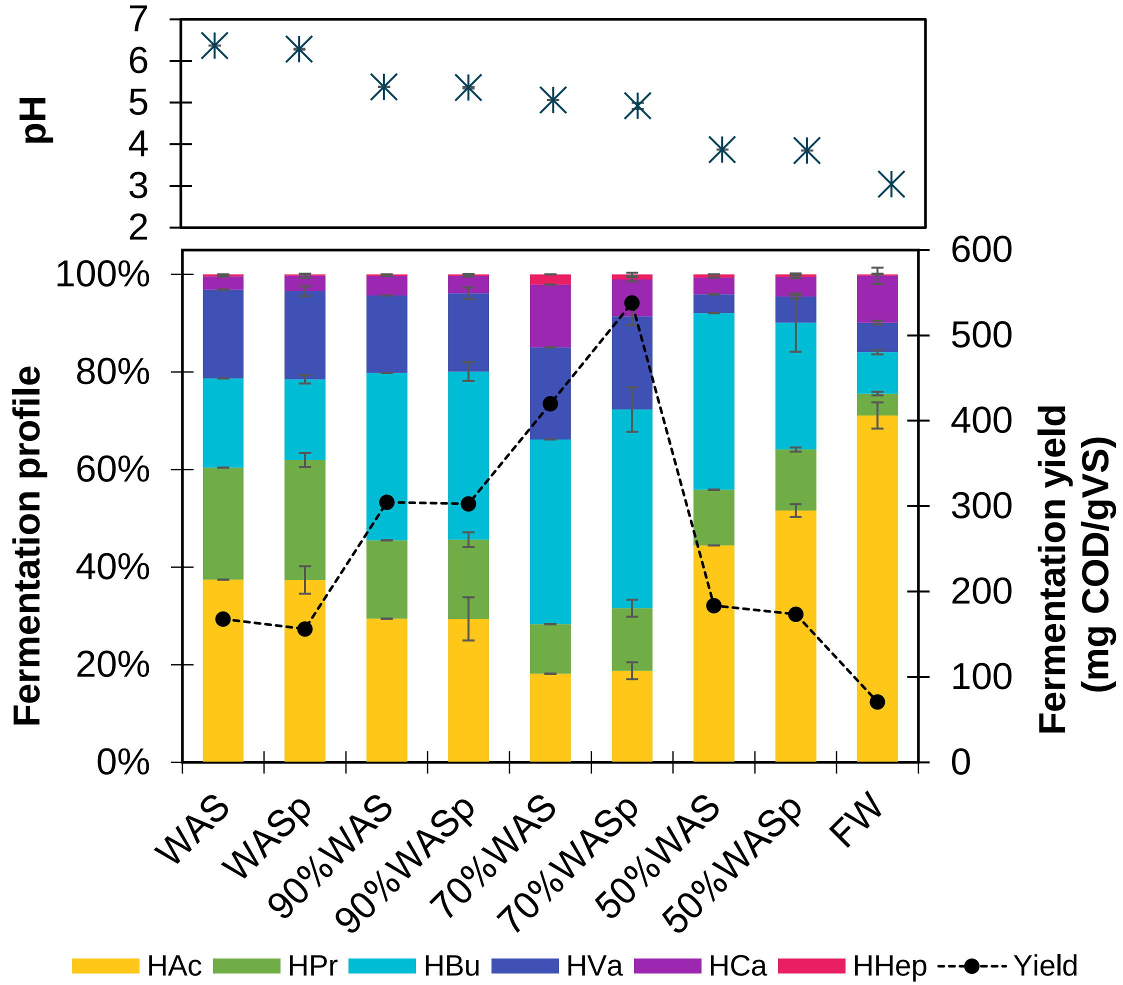


Auto-hydrolysis pre-treatment promotes WAS solubilisation but not WAS fermentation.

3. Impact of WAS auto-hydrolysis on co-fermentation performance

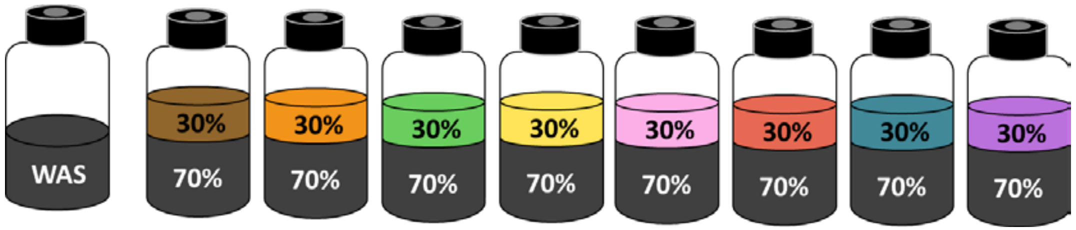
Auto-hydrolysis pre-treatment could speed up fermentation but does not increase WAS biodegradability.



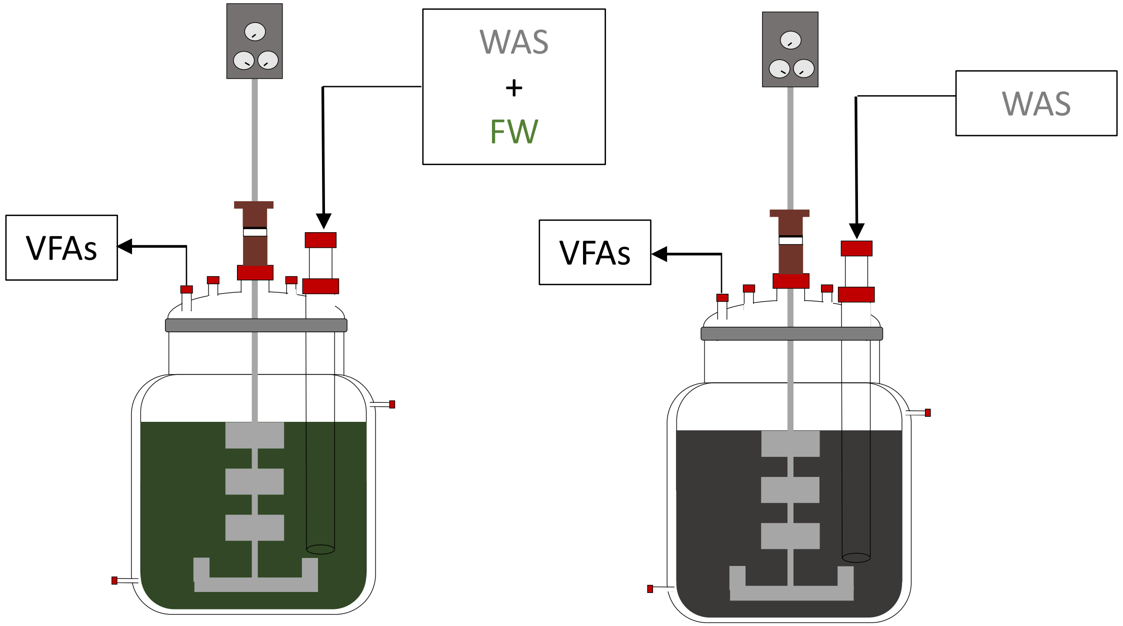


Ongoing research

- Impact of FW **composition** on co-fermentation performance.



- Continuous co-fermentation studies.



FW
Fruit
Vegetable
Pasta
Rice
Meat
Fish
Cellulose

Conclusions

- **Co-fermentation** mixtures obtained **higher VFA yield** than controls fermentation.
- Co-fermentation **yield increases** as the **proportion of FW increases** in the mixture.
- **Butyric** acid was enriched as the **proportion of FW** in the mixture increases.
- The proportion of **WAS** should be large enough to **keep pH above 5.0** without extra alkalinity.
- **Auto-hydrolysis** pre-treatment resulted in minor kinetics improvements but did **not improve the yield**.
- The **proportion** of substrates can be adjusted to **tune the product profile**.

For more information…

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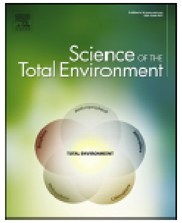

Check for updates

Assessing the potential of waste activated sludge and food waste co-fermentation for carboxylic acids production

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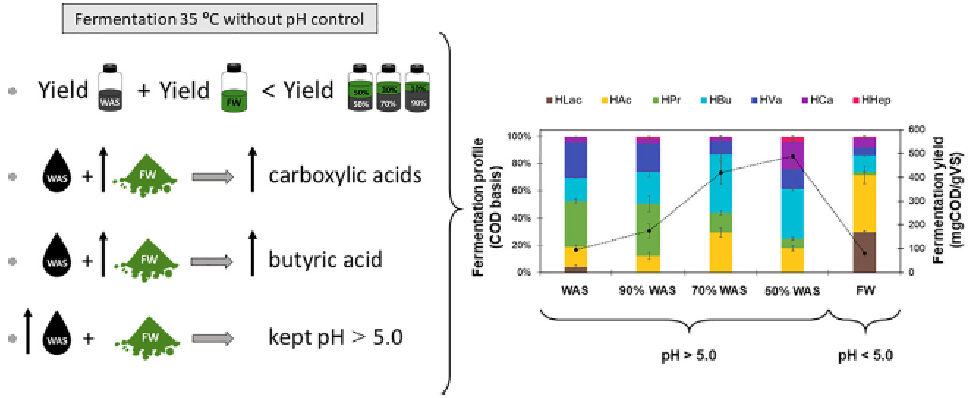
HIGHLIGHTS

- Co-fermentation yields were much higher than WAS and FW mono-fermentation yields.
- FW mono-fermentation was inhibited by pH and WAS helped to keep the pH above pH 5.0.
- Co-fermentation yields increased as the proportion of FW in the mixture increased.
- Maximum co-fermentation yield was 480 mgCOD/gVS for the 50/50% mixture (VS-basis).
- Butyric acid was favoured by FW, while WAS favoured acetic and propionic acid.

GRAPHICAL ABSTRACT



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