



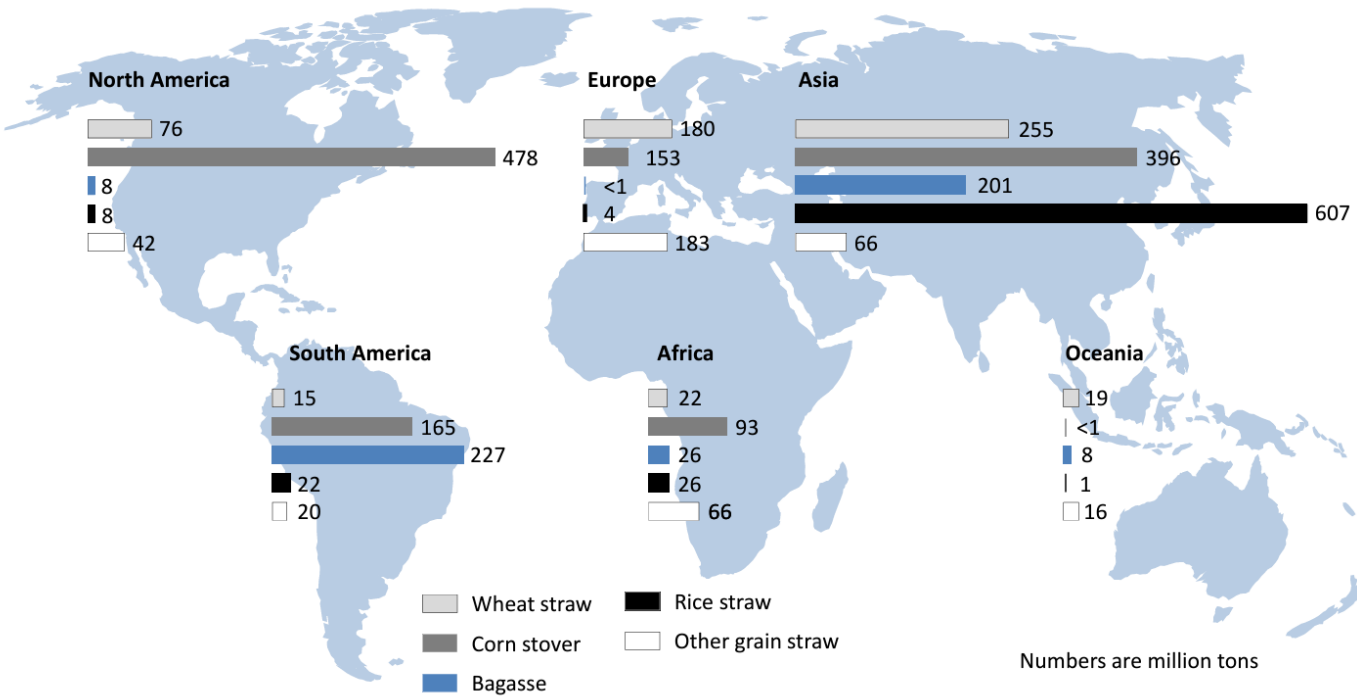
**Bridging waste to value
through anaerobic digestion**

Kinetic limitations in xylan conversion to caproate

Juan Iglesias-Riobó, Camila Machado-Fernández, Miguel Mauricio-Iglesias, Marta Carballa

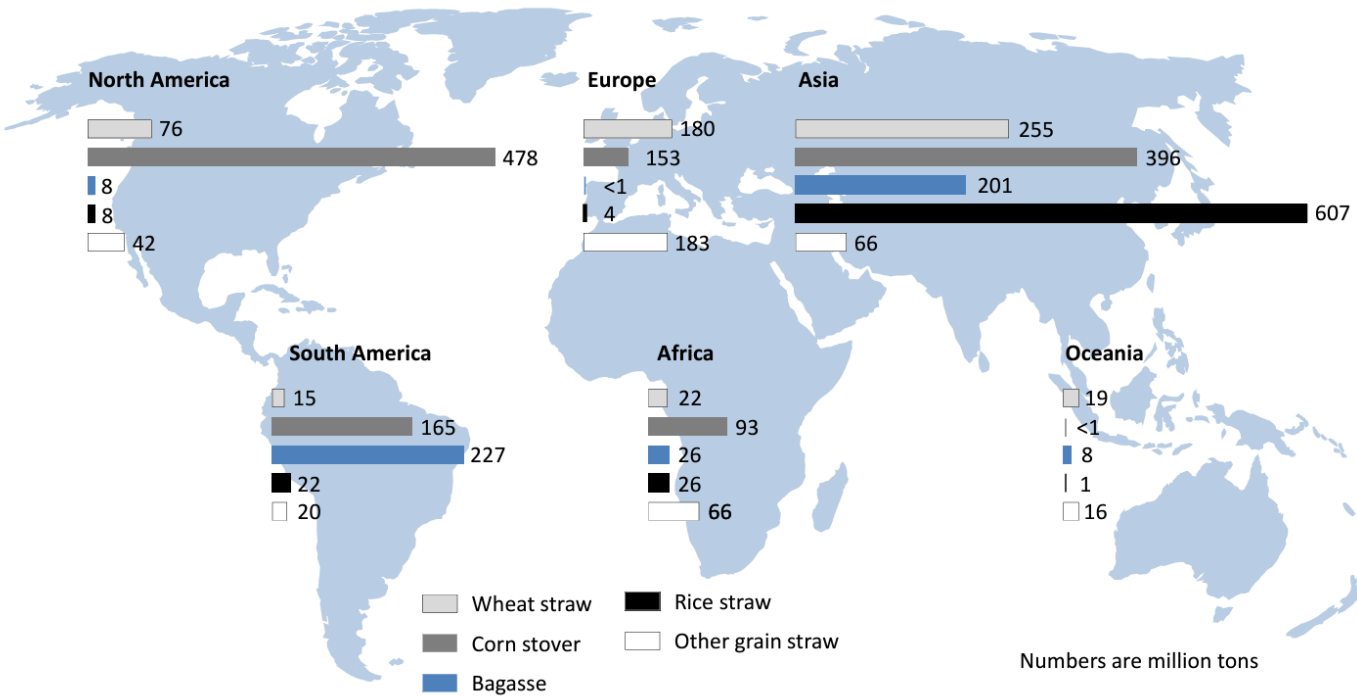
*Department of Chemical Engineering
Universidade de Santiago de Compostela*

Lignocellulosic wastes are found all over the world



Estimates of lignocellulosic waste materials available globally for bioproduction (Philp & Winickoff, 2018)

... but its variable composition might affect valorisation

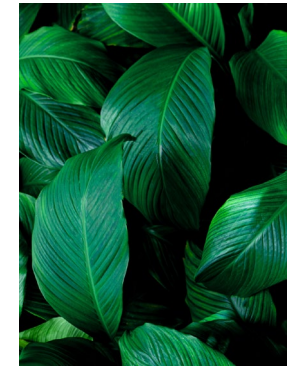


Estimates of lignocellulosic waste materials available globally for bioproduction (Philp & Winickoff, 2018)



Rice straw

- Lignin ≈ 13 %
- Cellulose ≈ 30 %
- Hemicellulose ≈ 24 %



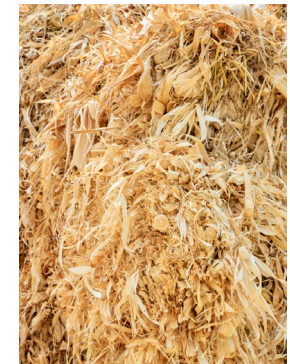
Leaves

- Lignin ≈ NA
- Cellulose ≈ 17 %
- Hemicellulose ≈ 82 %



Eucalyptus

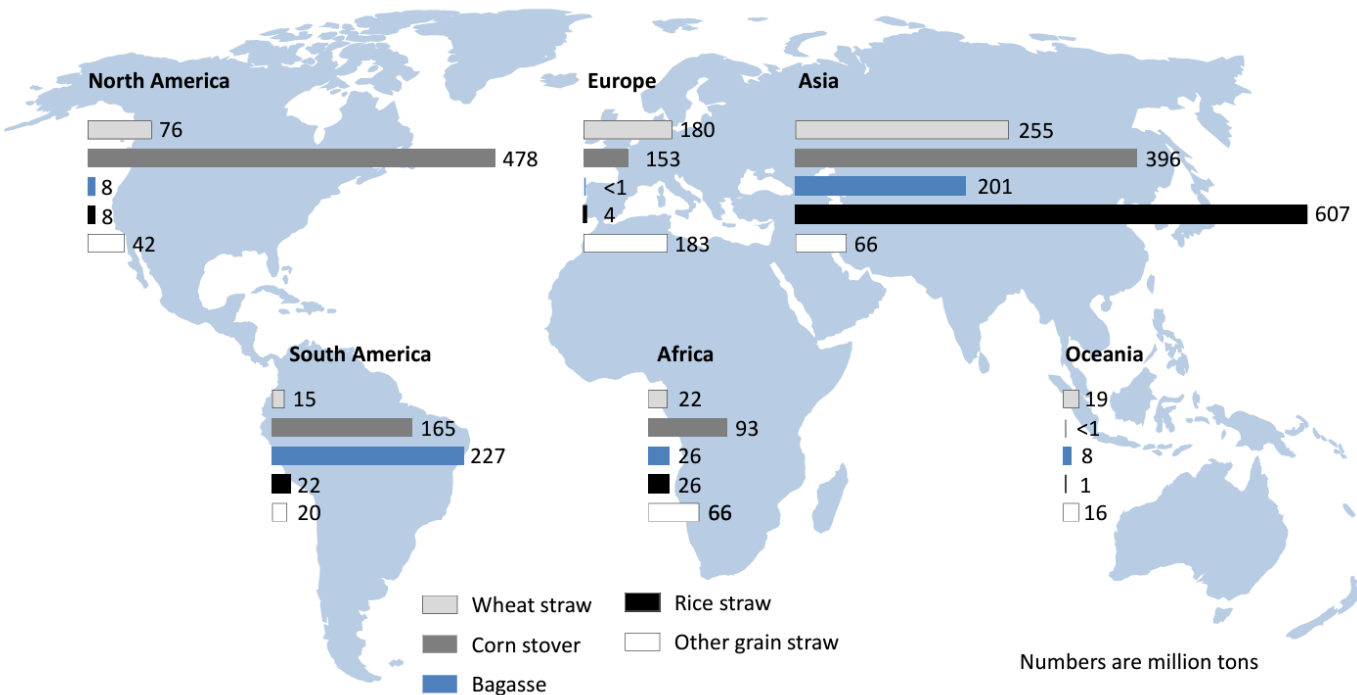
- Lignin ≈ 30 %
- Cellulose ≈ 40 %
- Hemicellulose ≈ 12 %



Corn stover

- Lignin ≈ 18 %
- Cellulose ≈ 38 %
- Hemicellulose ≈ 32 %

Hemicellulose is the least studied fraction

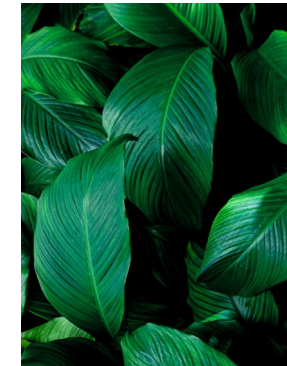


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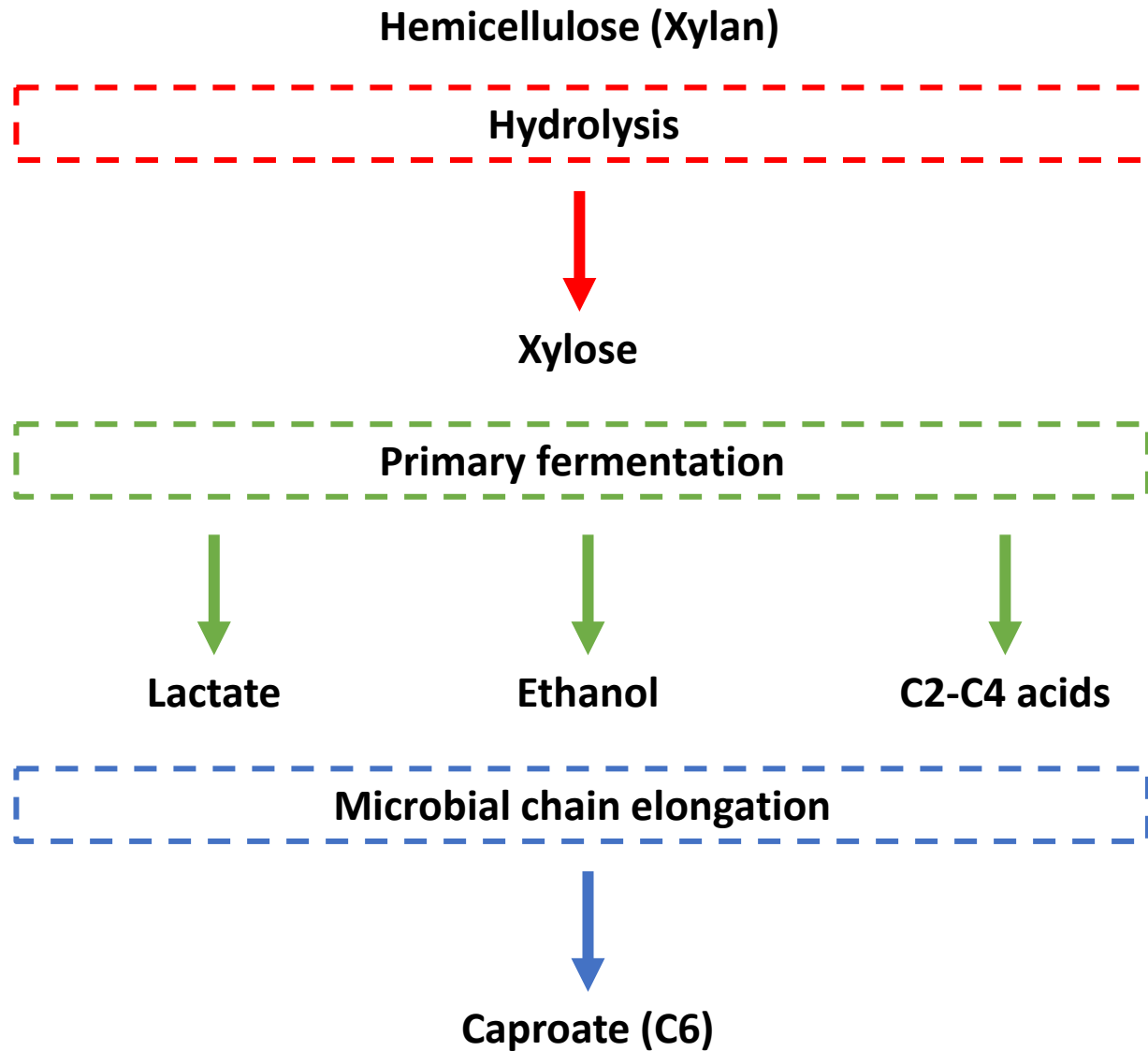
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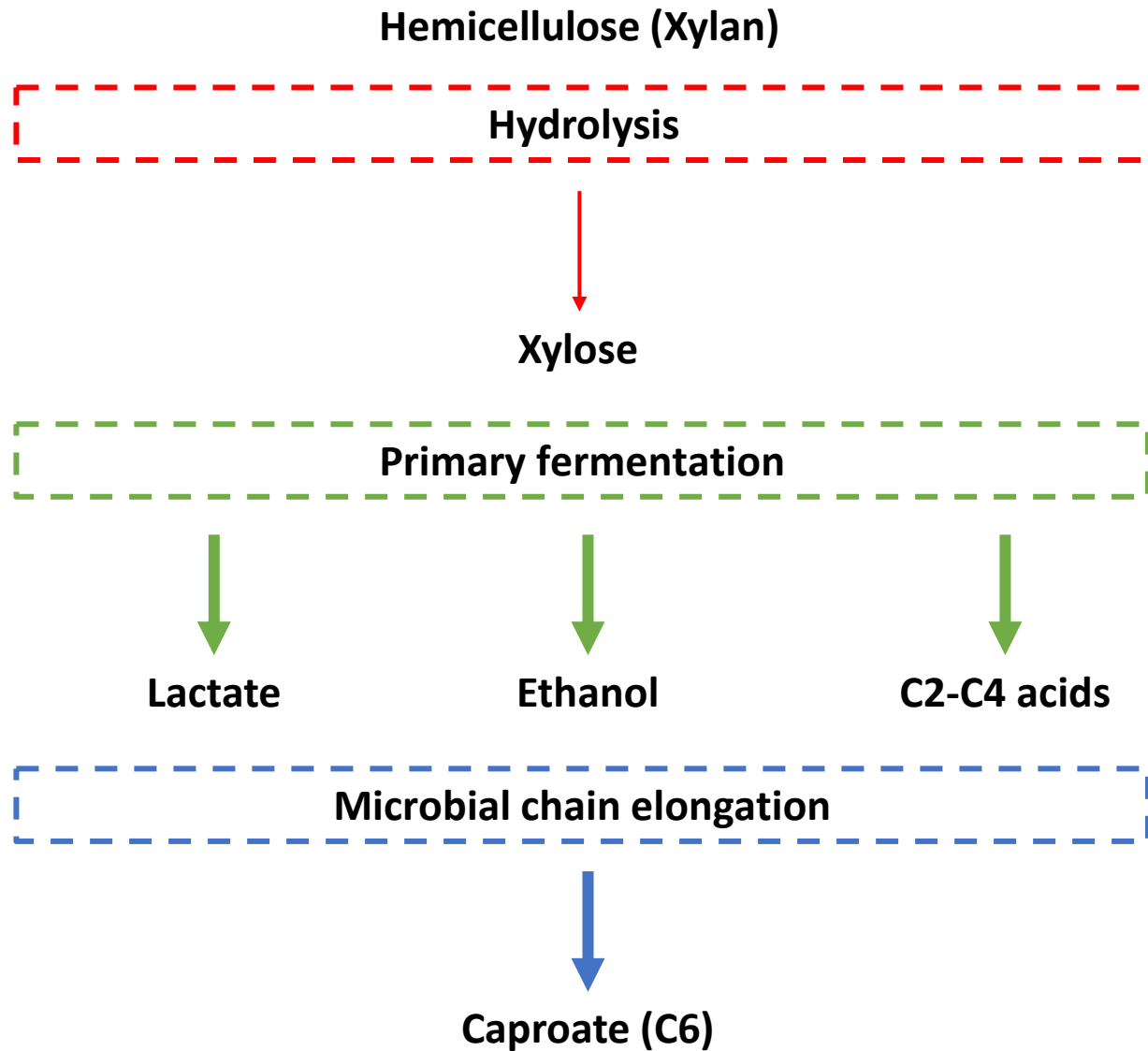
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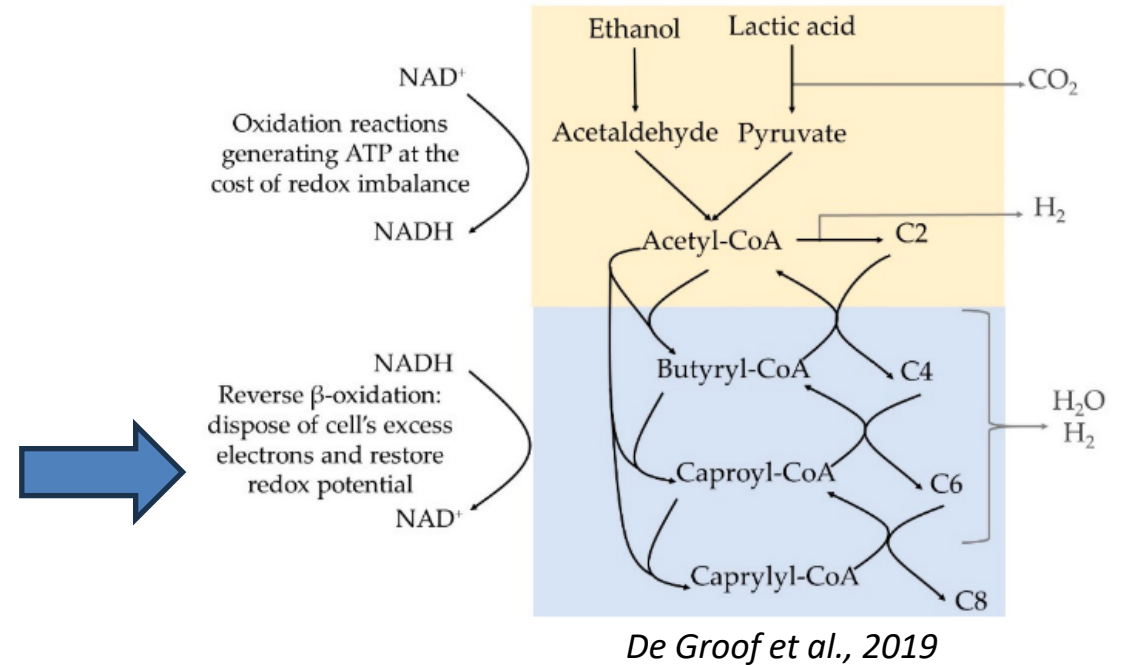
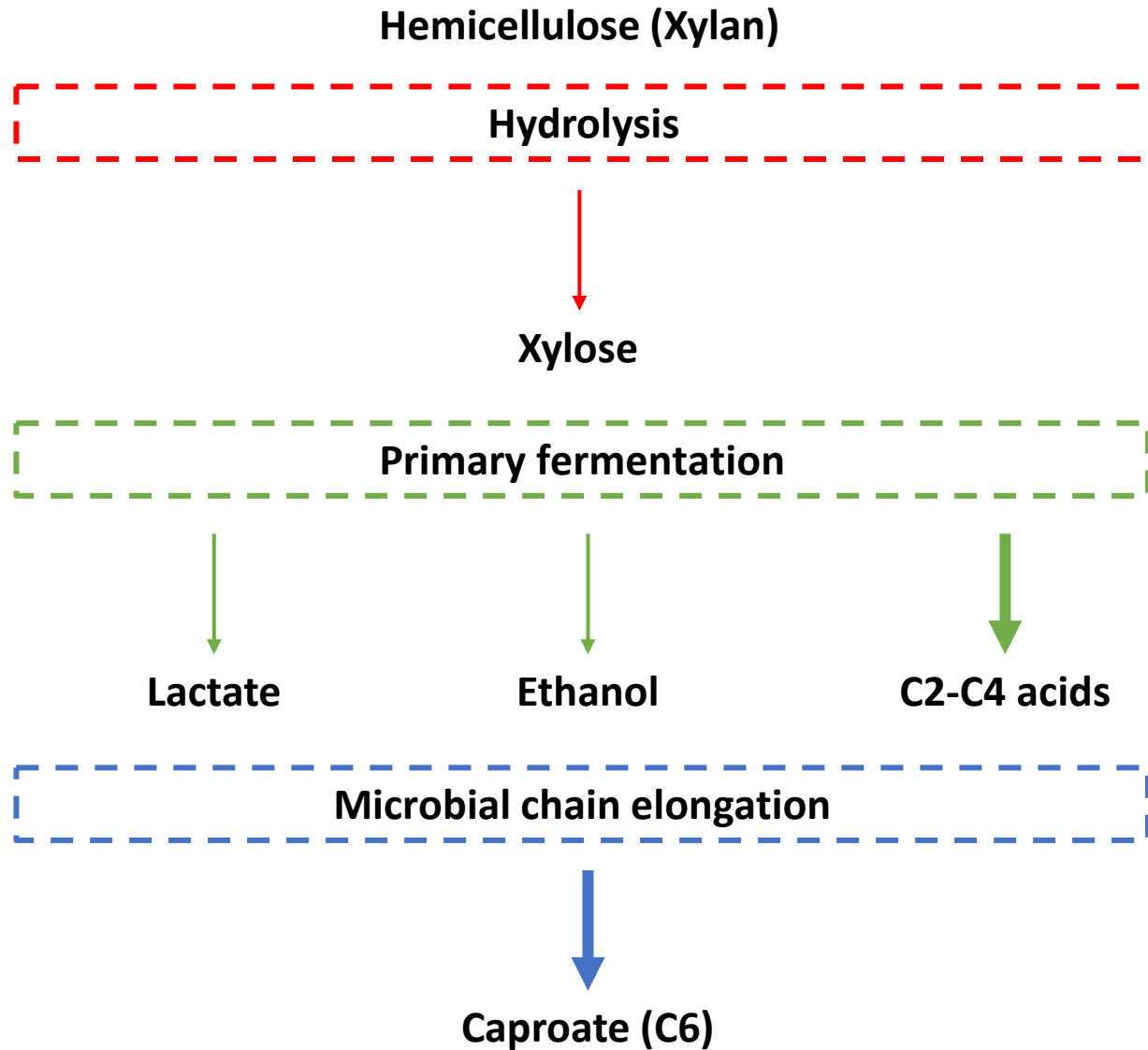
Scheme of xylan conversion to caproate



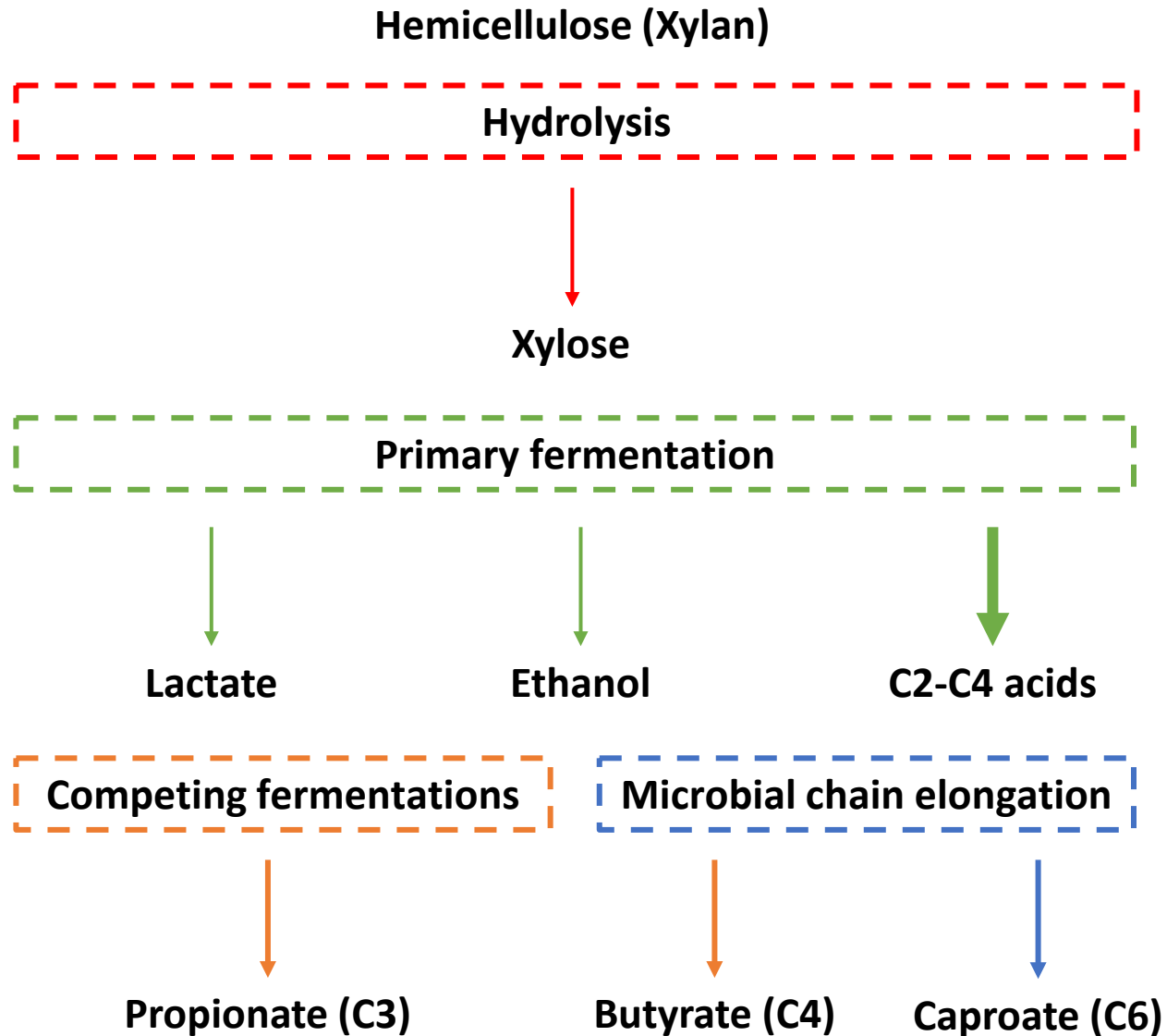
Hydrolysis is the first challenge to face



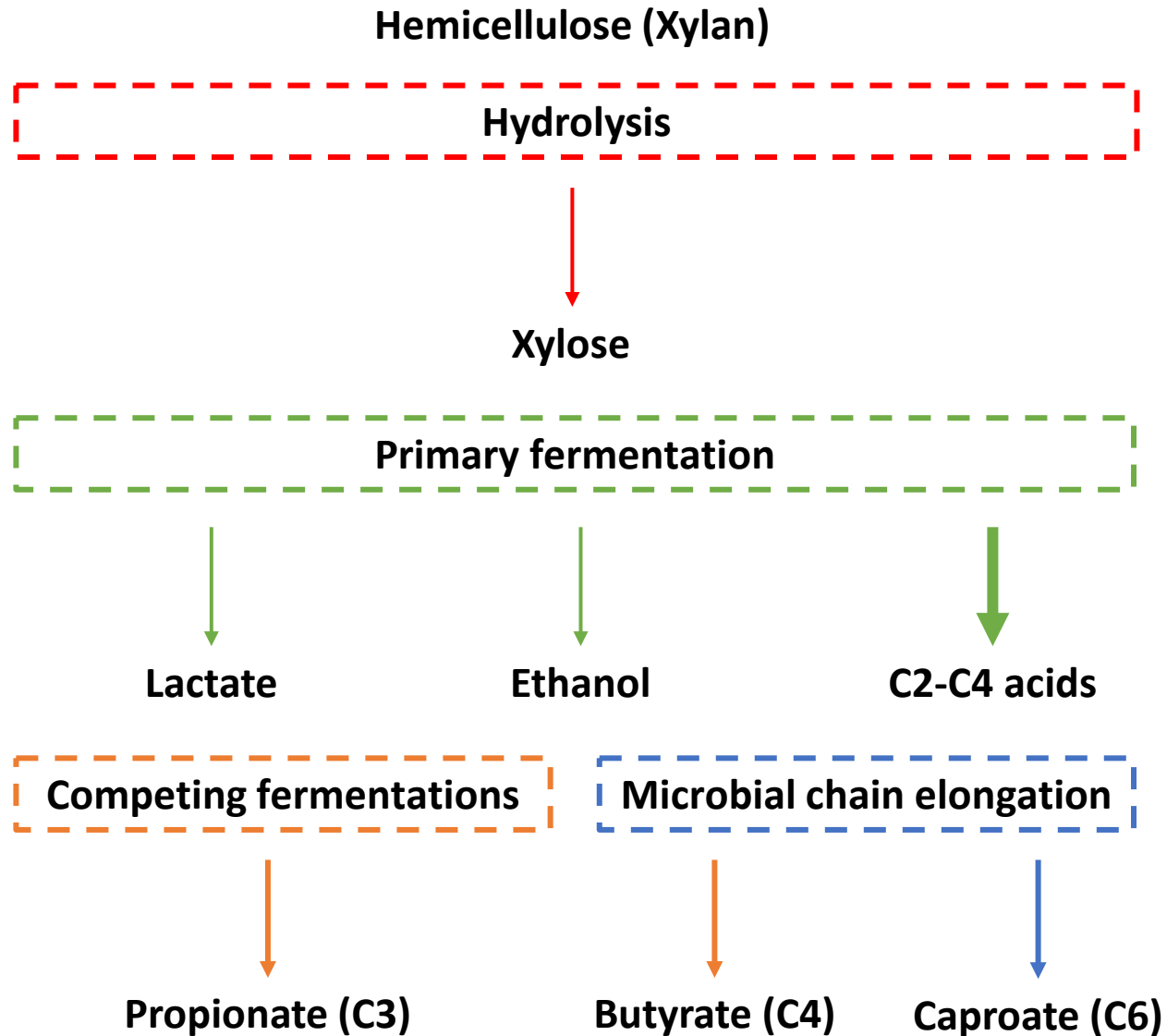
Lactate and/or ethanol availability is the second challenge



Chain elongation stage competes with several metabolic routes



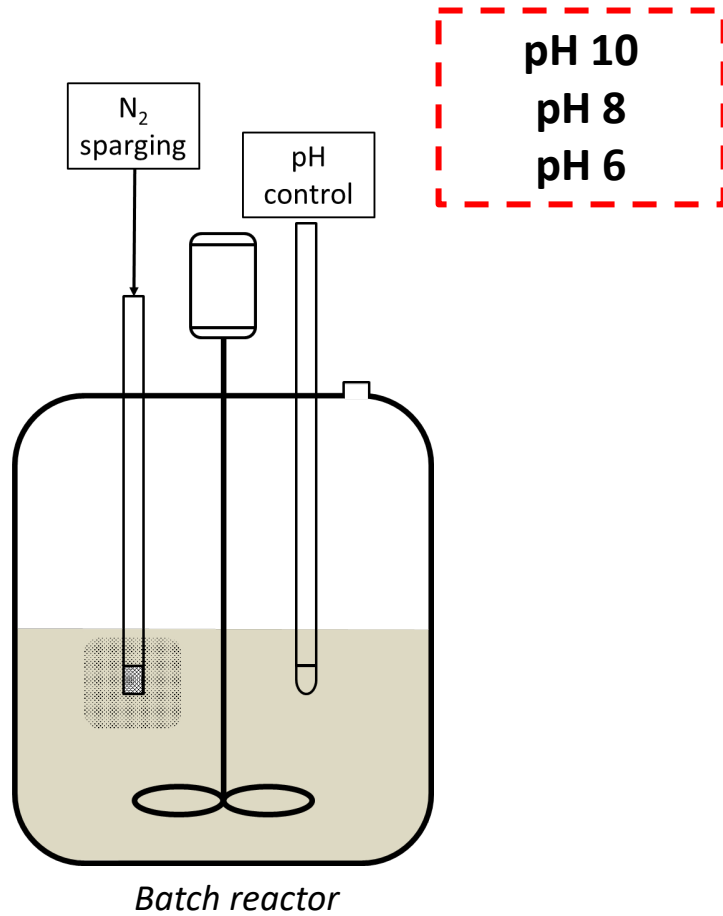
Chain elongation stage competes with several metabolic routes



Objective:

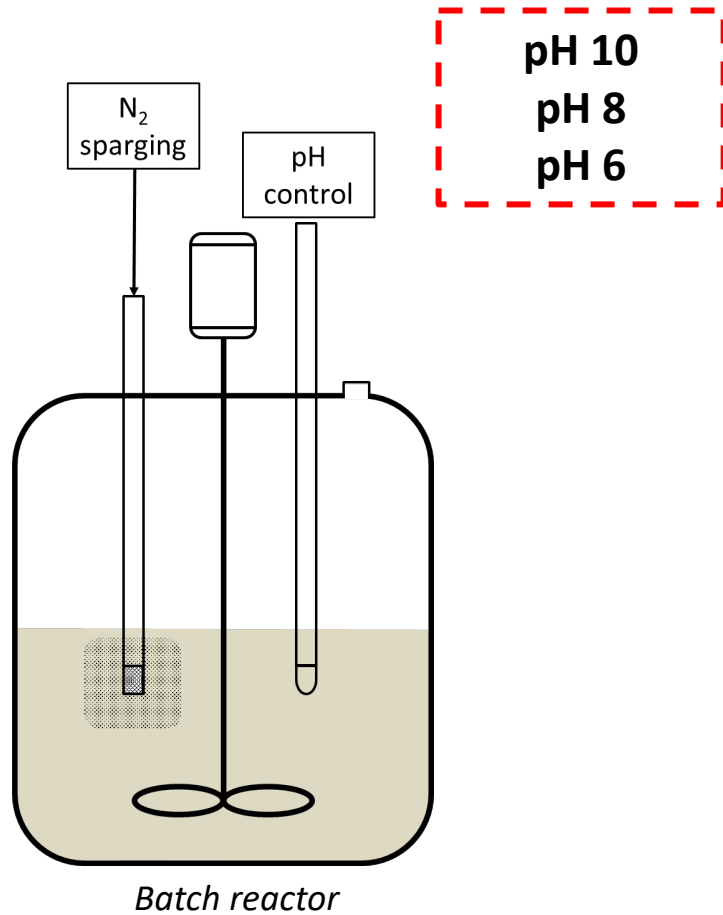
Study the kinetic limitations to optimise the xylan conversion to caproate in a single stage process by modifying operational parameters.

Kinetic limitations caused by pH

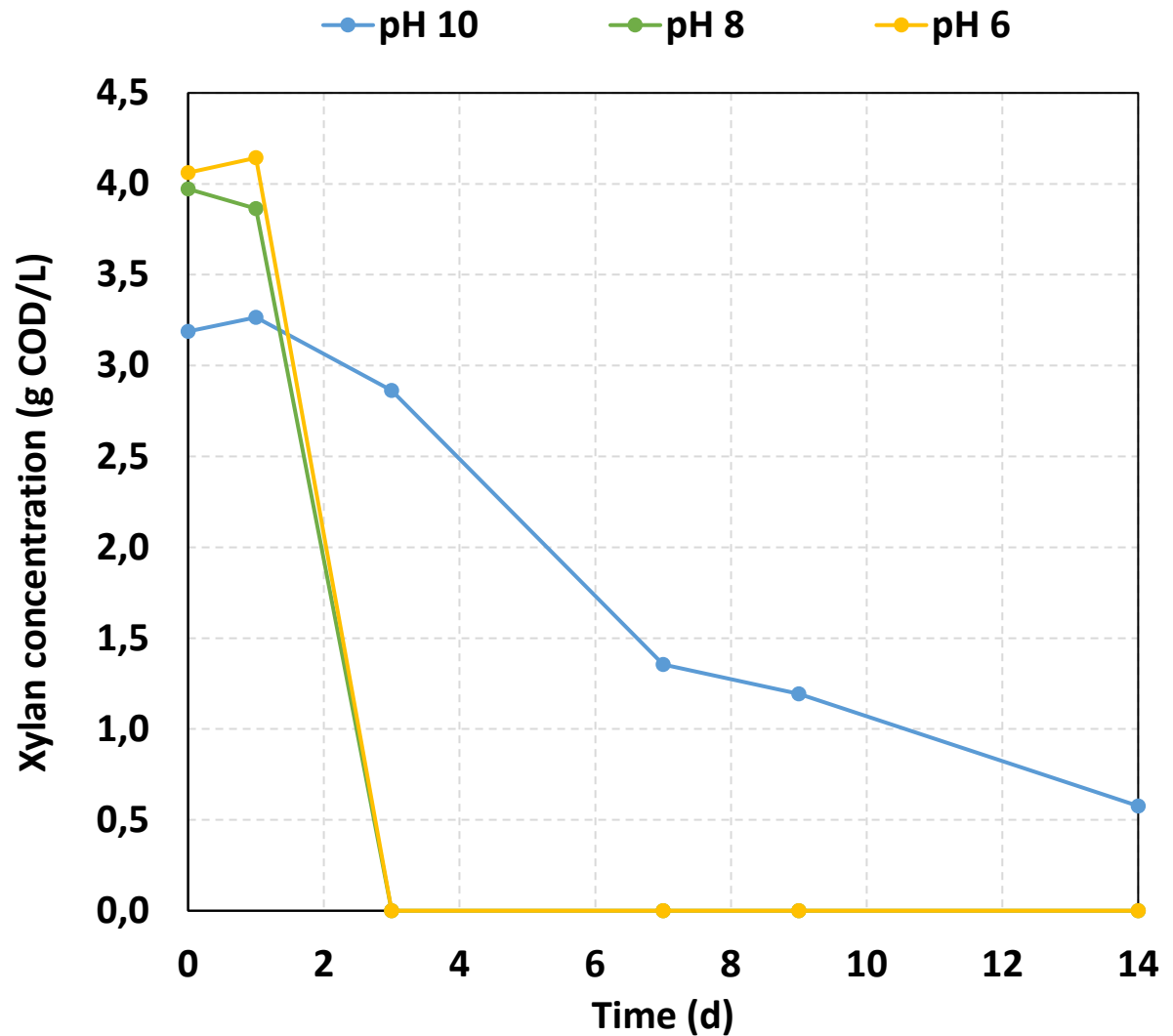


- **Mixed-culture fermentation**
- **Xylan as sole carbon source**
- **Mineral medium**

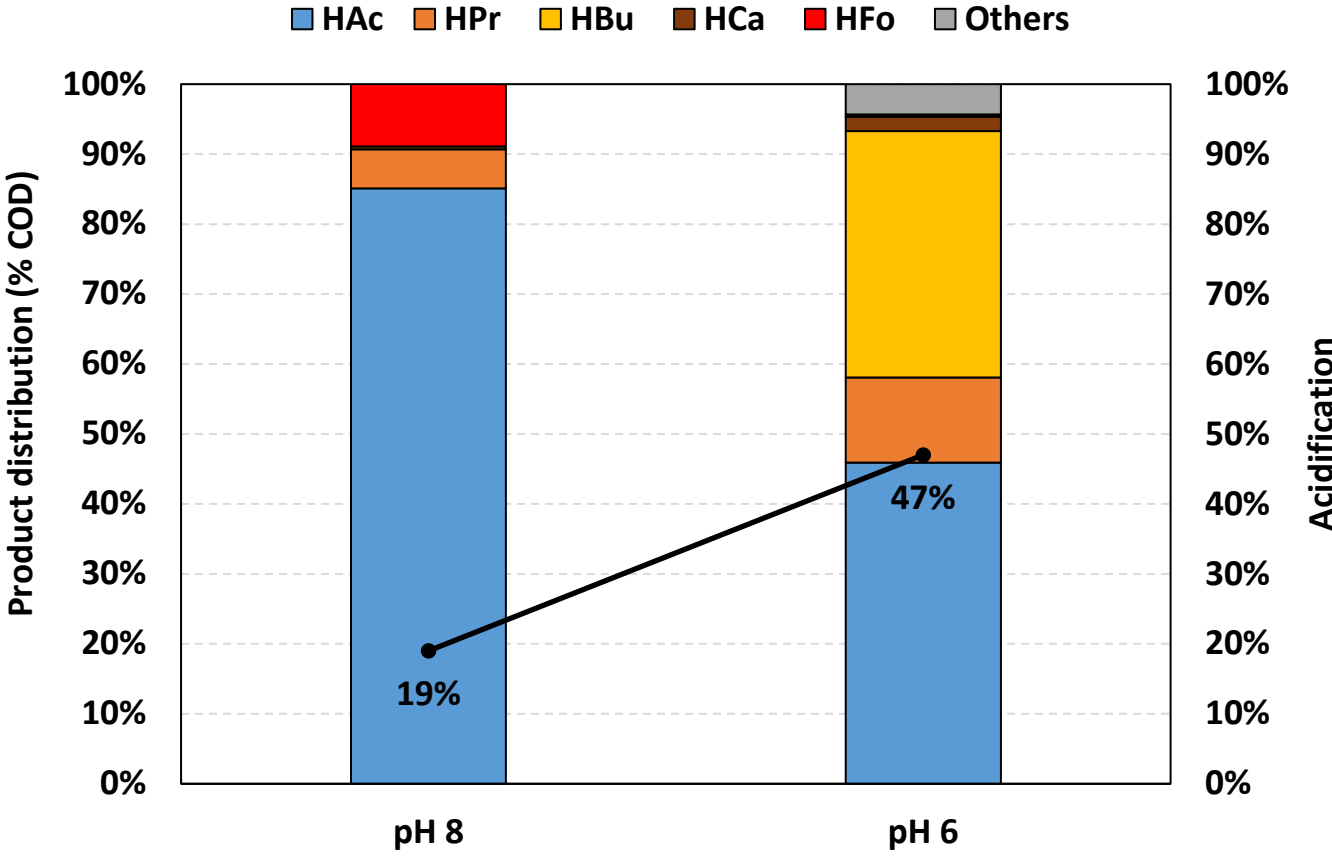
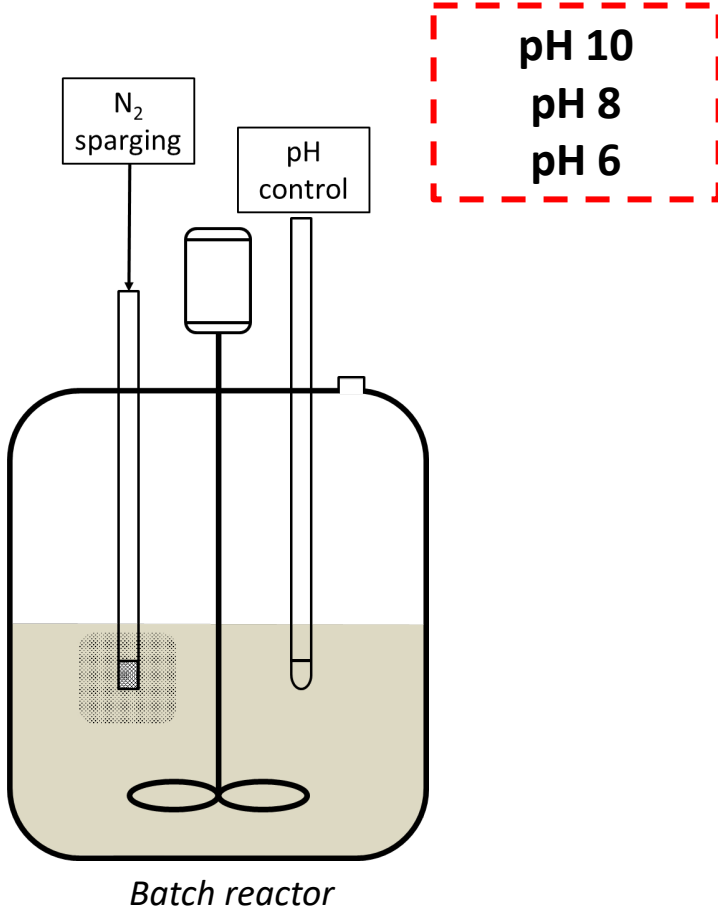
The pH 10 reported the lowest hydrolysis rate



- Mixed-culture fermentation
- Xylan as sole carbon source
- Mineral medium



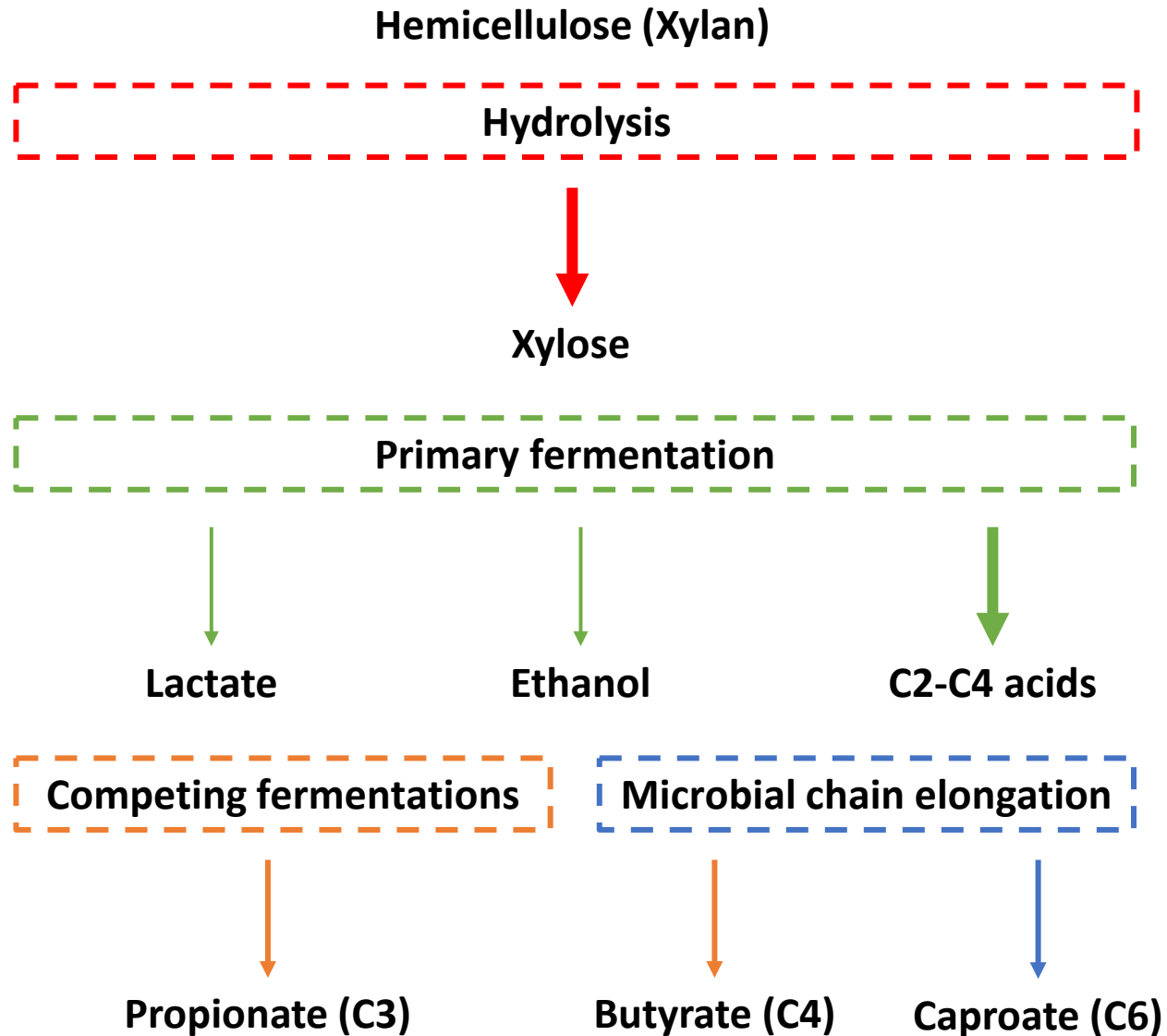
... pH 6 showed the greatest selectivity towards butyrate and caproate



- Mixed-culture fermentation
- Xylan as sole carbon source
- Mineral medium

$$Acidification (\%) = \frac{\sum C_{carboxylates}}{C_{xylan}} \times 100$$

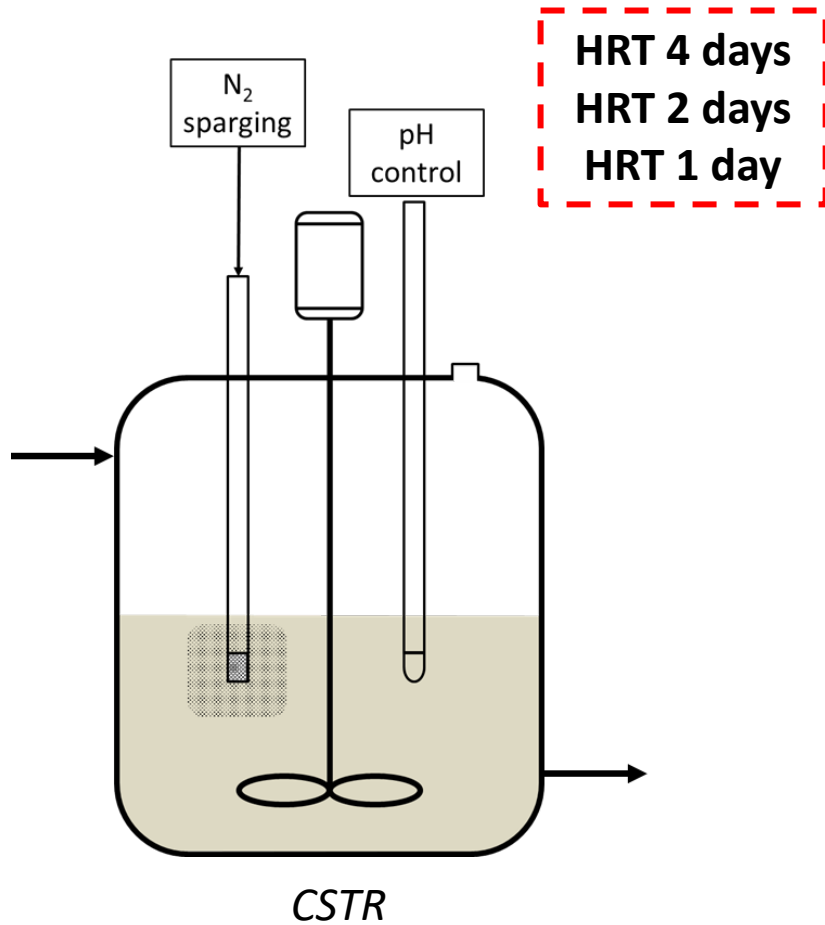
Hydrolysis is not limiting under acidic conditions



Main challenges:

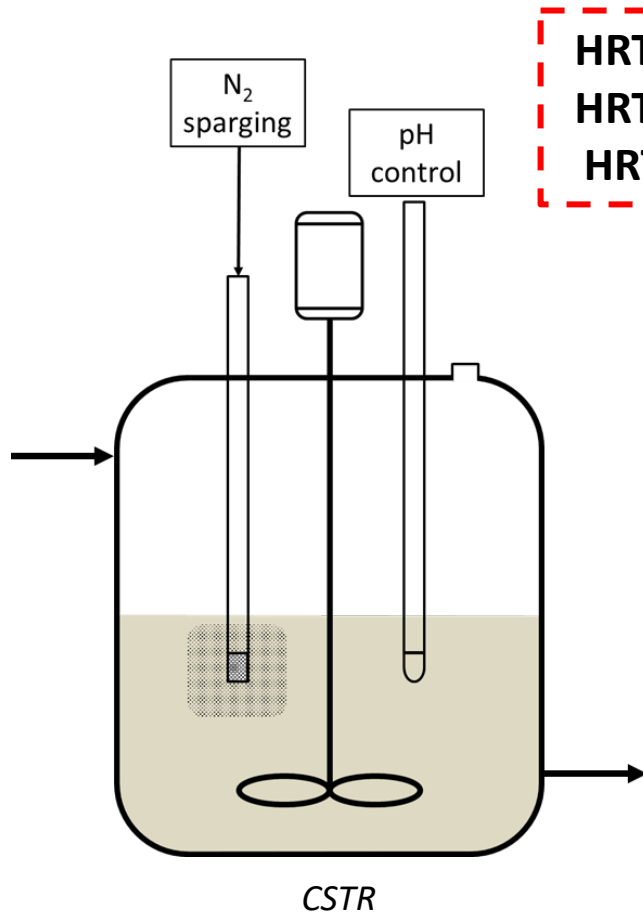
- **Xylan hydrolysis:** avoided under acidic conditions ✓
- **Electron donor availability** ? → **HRT**

Experimental planning. Kinetic limitations caused by HRT



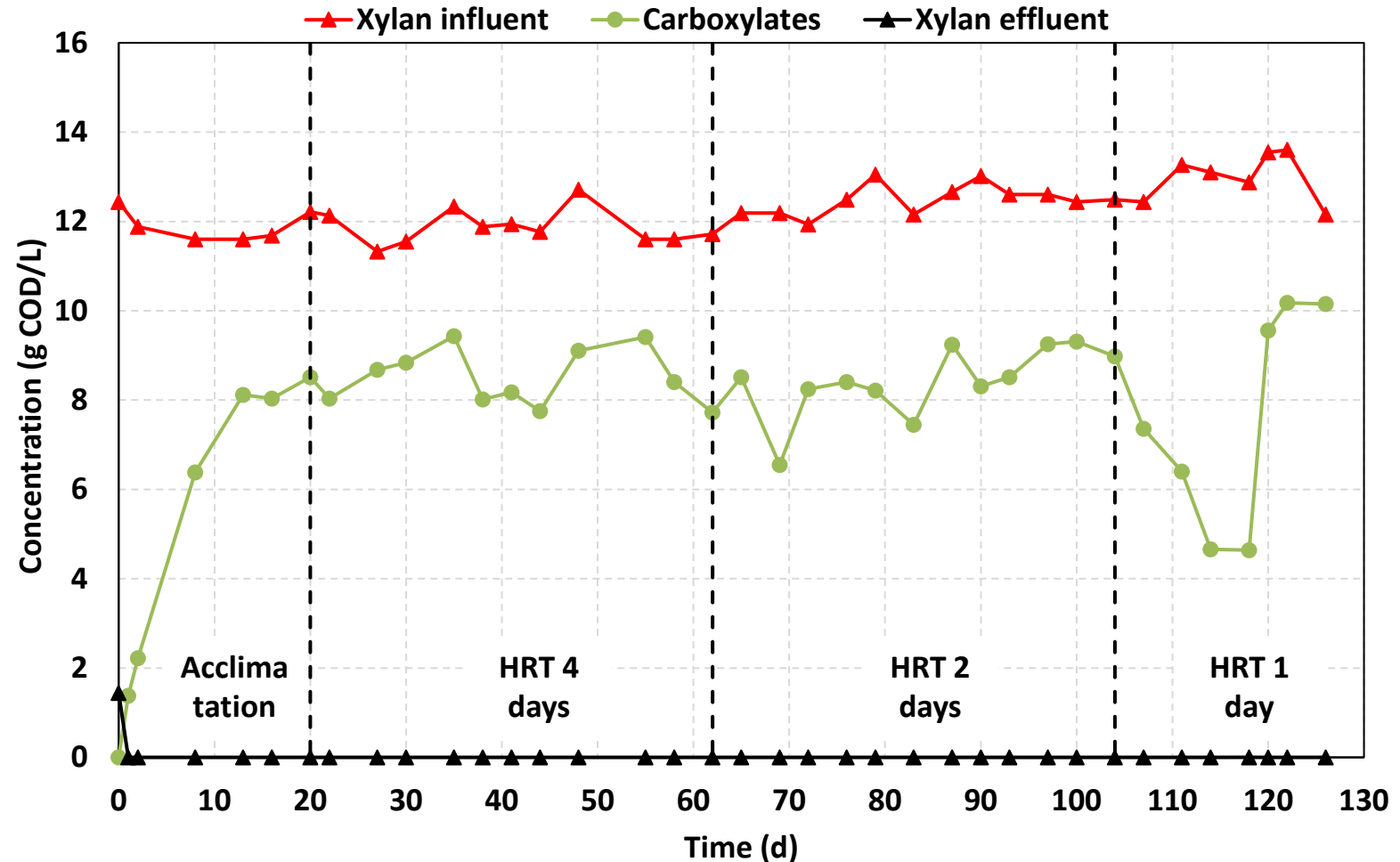
- pH 6
- Mixed-culture fermentation
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HRT did not affect xylan conversion to carboxylates...

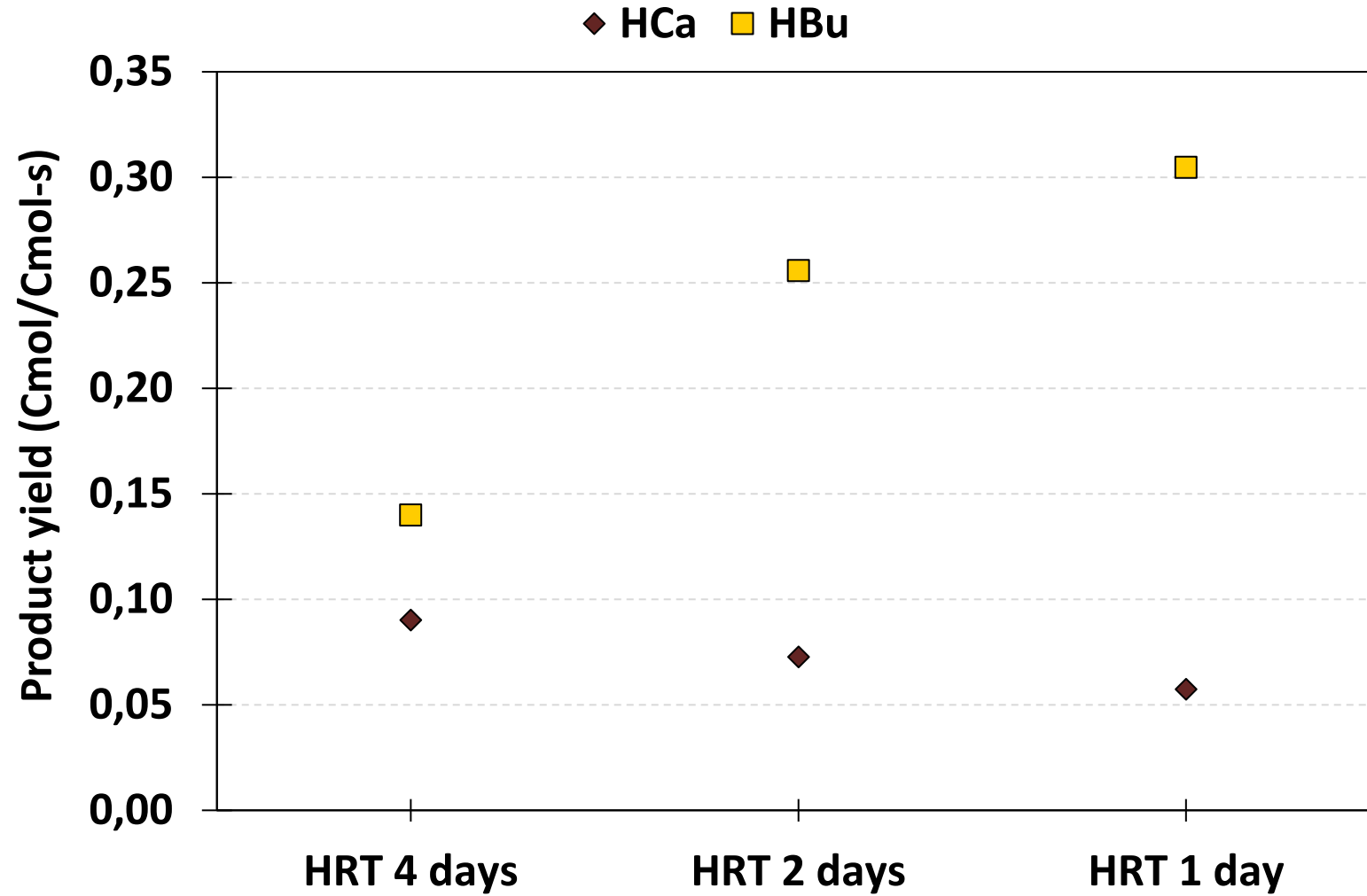


HRT 4 days
HRT 2 days
HRT 1 day

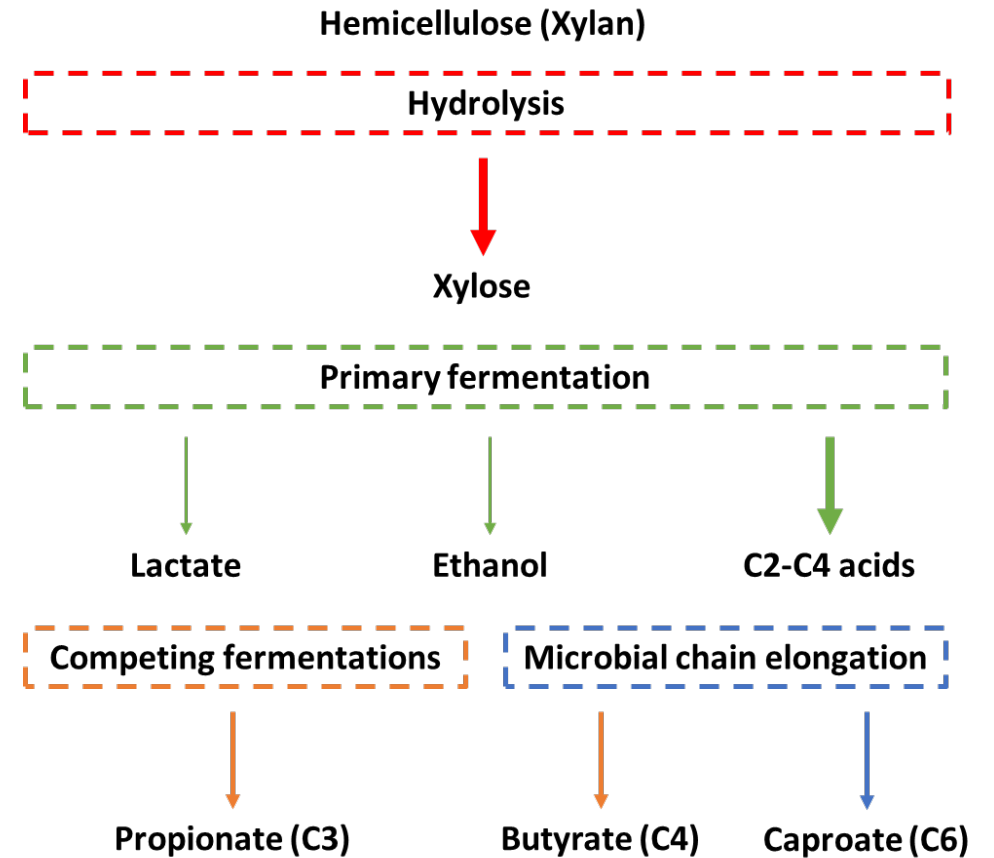
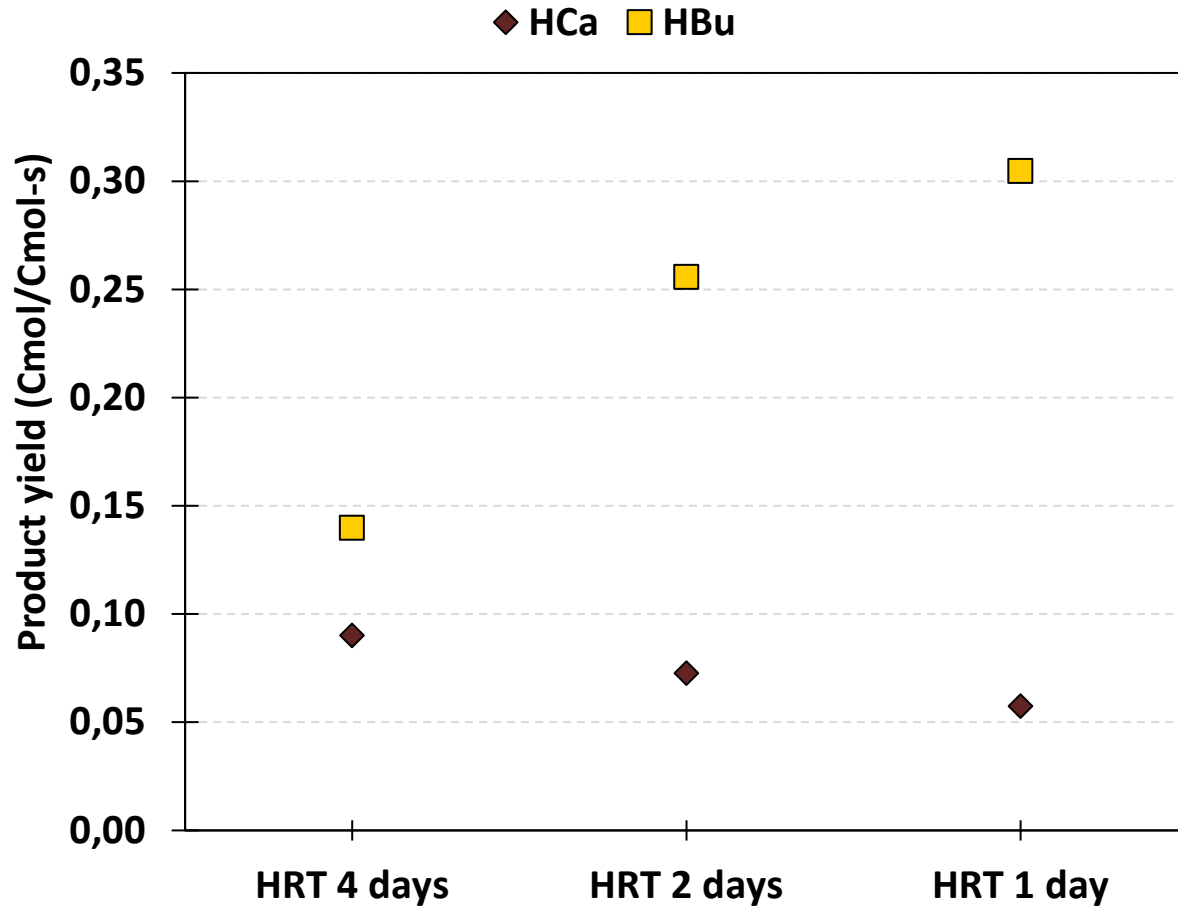
- pH 6
- Mixed-culture fermentation
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... but it changed product selectivity



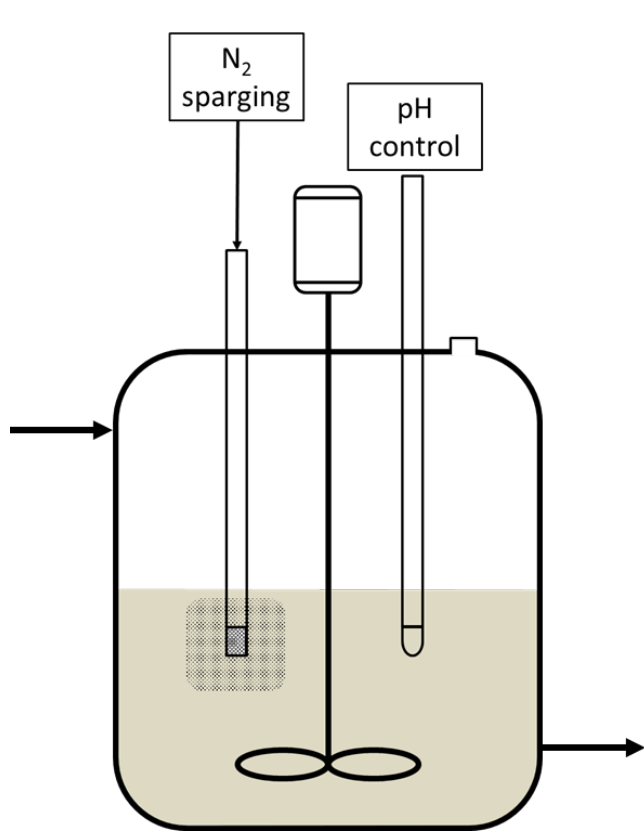
... but it changed product selectivity



Butyrate chain elongation outcompetes caproate chain elongation pathway at low HRT

- Microbial growth limitation (SRT)
- Kinetic limitation (HRT)

CSTR vs SBR



Continuous Stirred Tank
Reactor (CSTR)

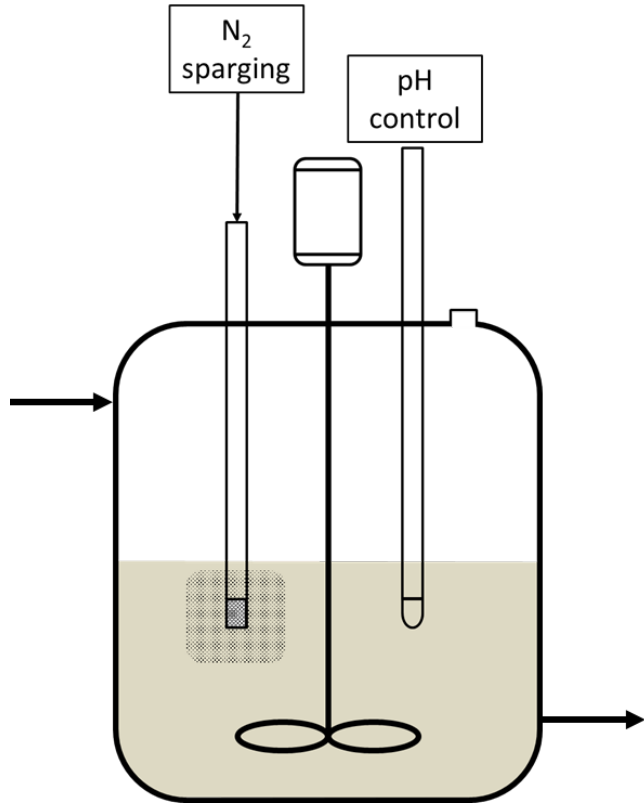
CSTR
Fed continuously
Low substrate concentration
HRT = SRT

$$HRT = \frac{V}{Q}$$

$$SRT = \frac{X_{in}}{X_{out}} \cdot HRT$$

- V: Reactor volume
- Q: Flow rate
- X: Biomass concentration

CSTR vs SBR



Continuous Stirred Tank Reactor (CSTR)

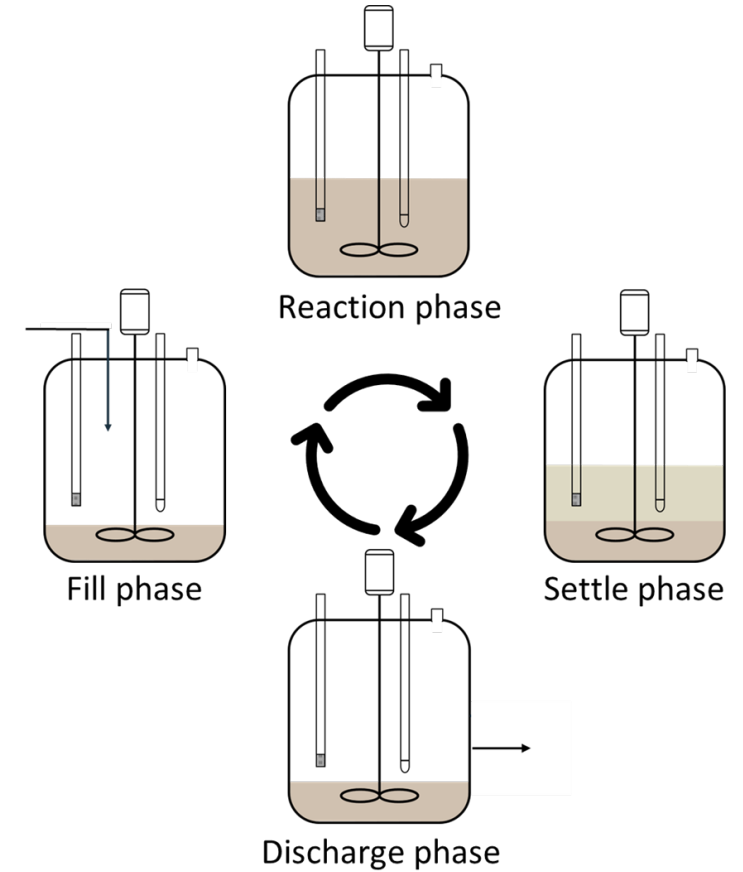
CSTR
Fed continuously
Low substrate concentration
HRT = SRT

SBR
Pulse-fed
High/Low substrate concentration
HRT ≠ SRT

$$HRT = \frac{V}{Q}$$

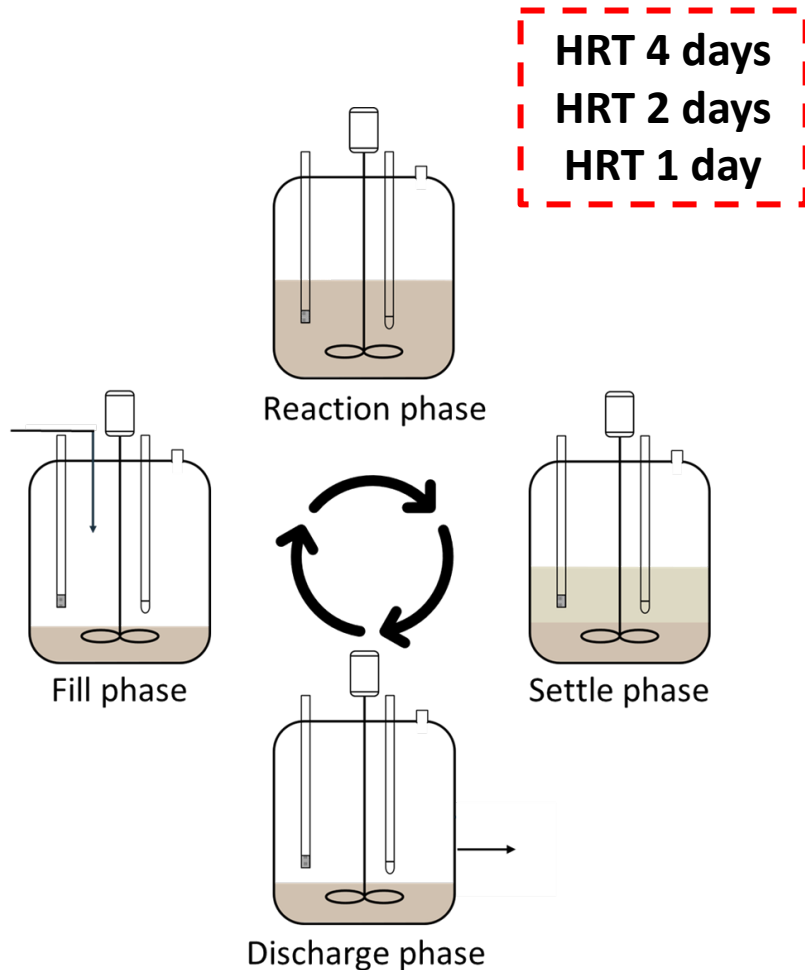
$$SRT = \frac{X_{in}}{X_{out}} \cdot HRT$$

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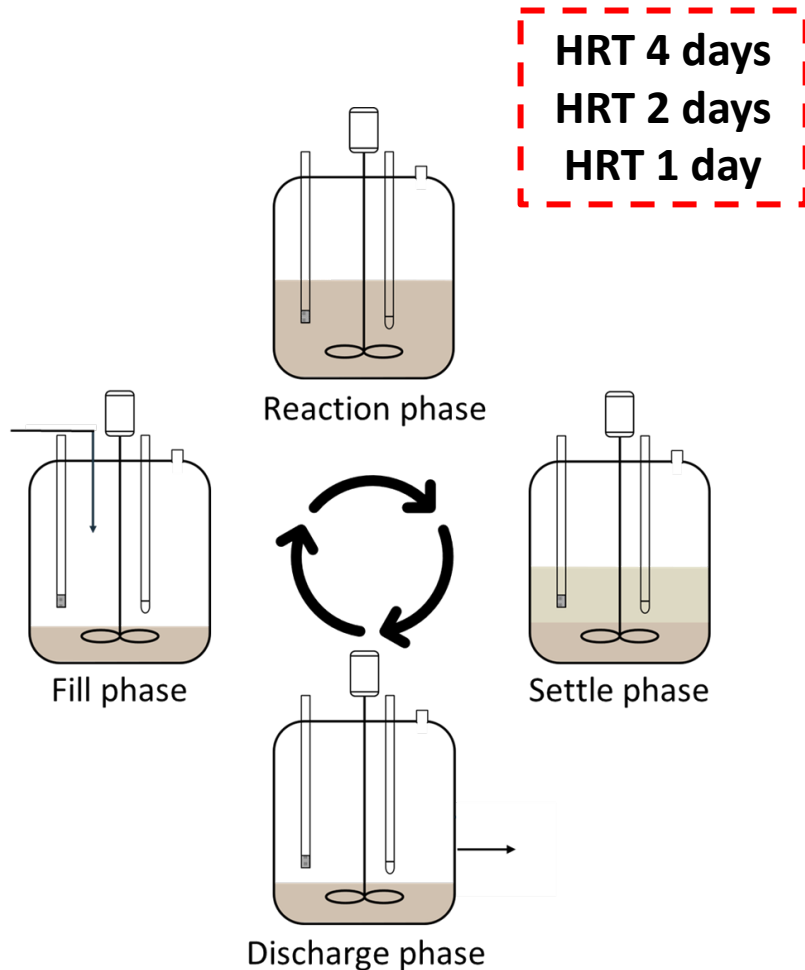
Sequential Batch Reactor (SBR)

Experimental planning. Are the HRT or the SRT key parameters?

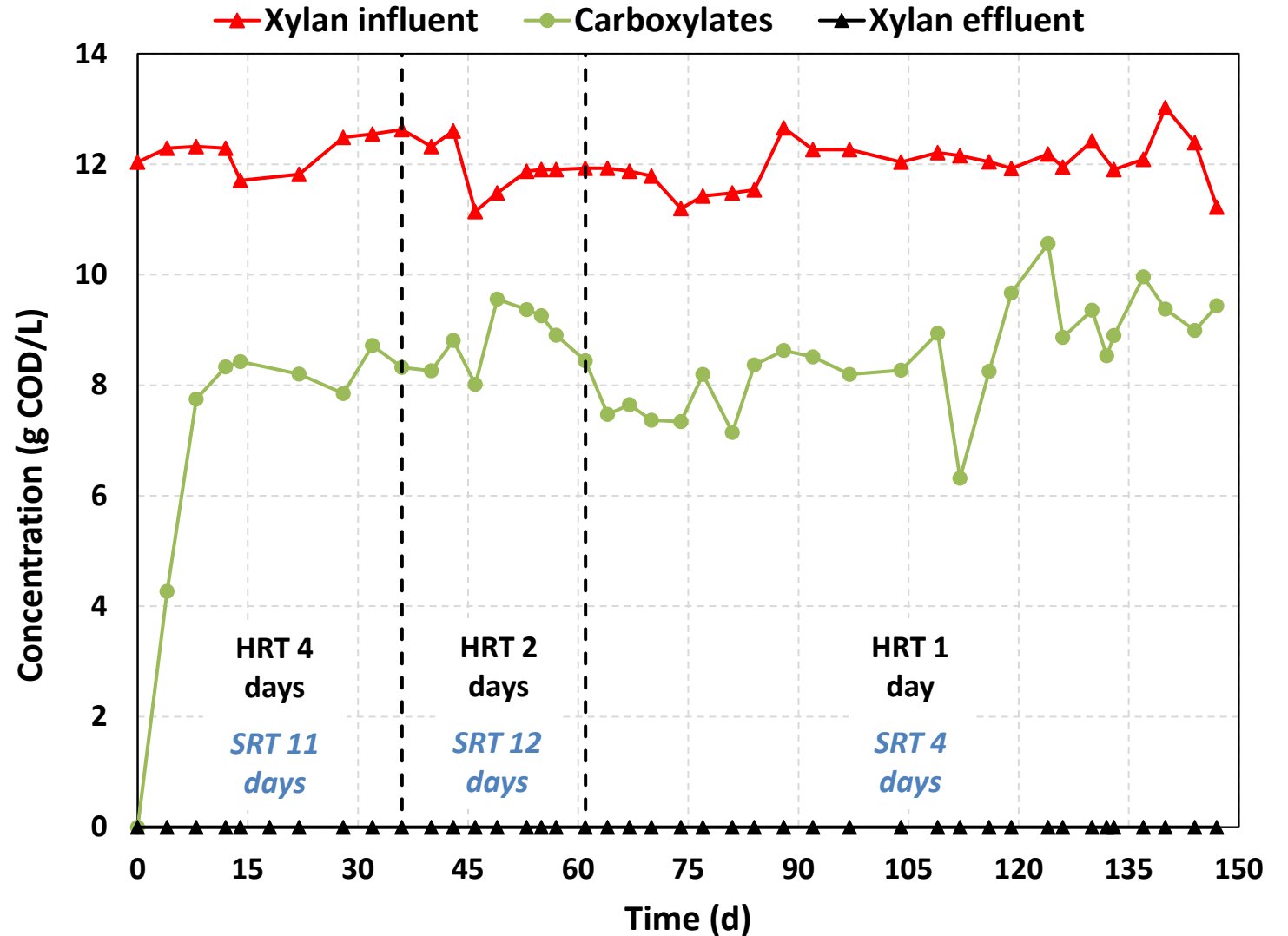


- pH 6
- Mixed-culture fermentation
- Xylan as sole carbon source
- Mineral medium

Xylan was fully converted regardless HRT or reactor mode



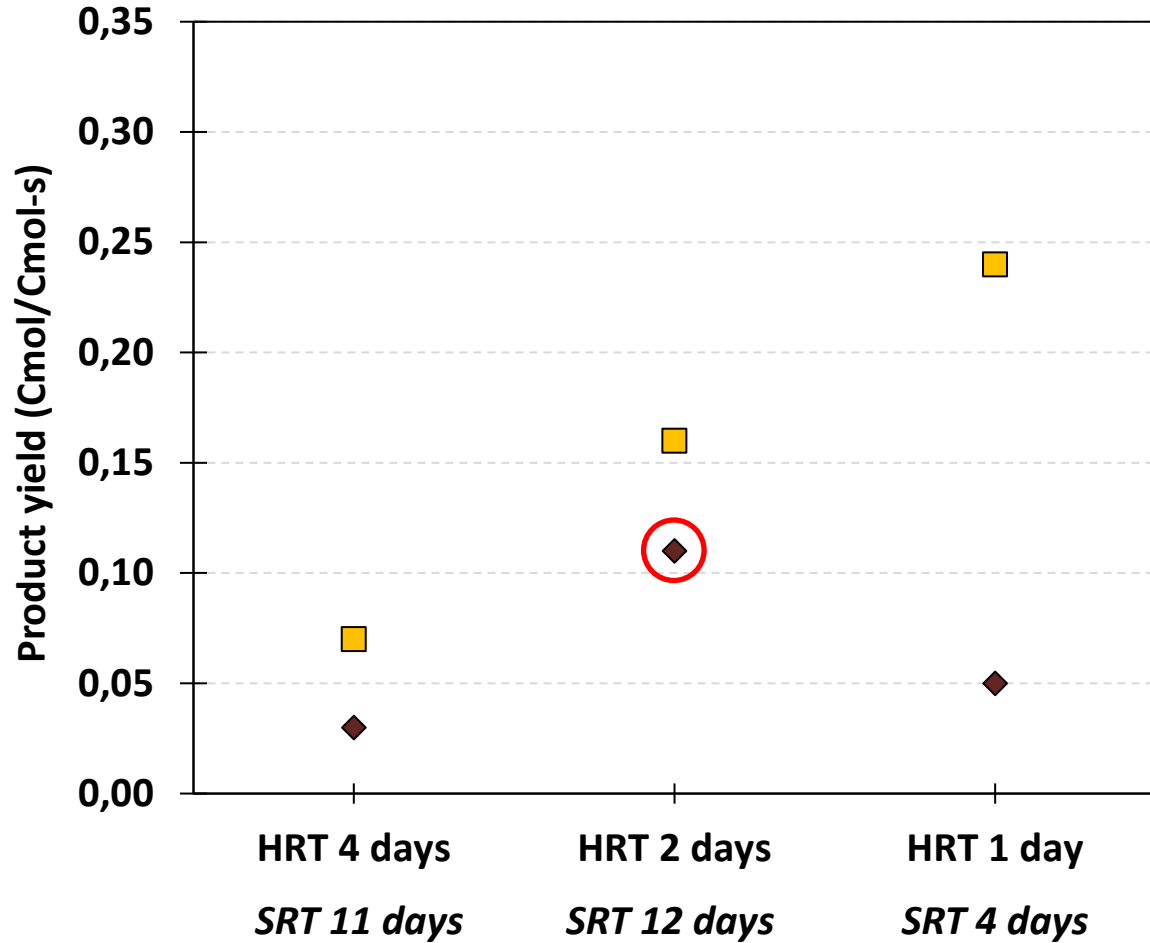
- pH 6
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HCa yield is not directly affected by HRT/SRT value

SBR operation

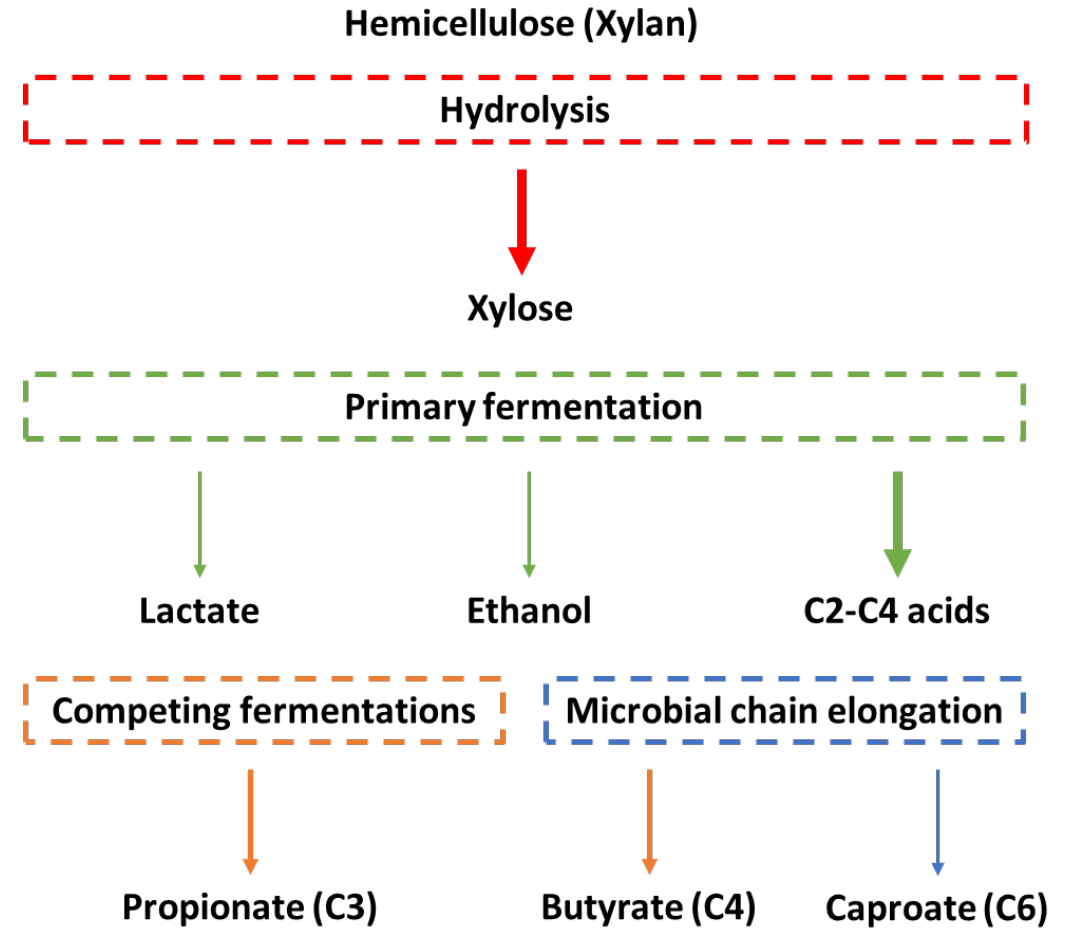
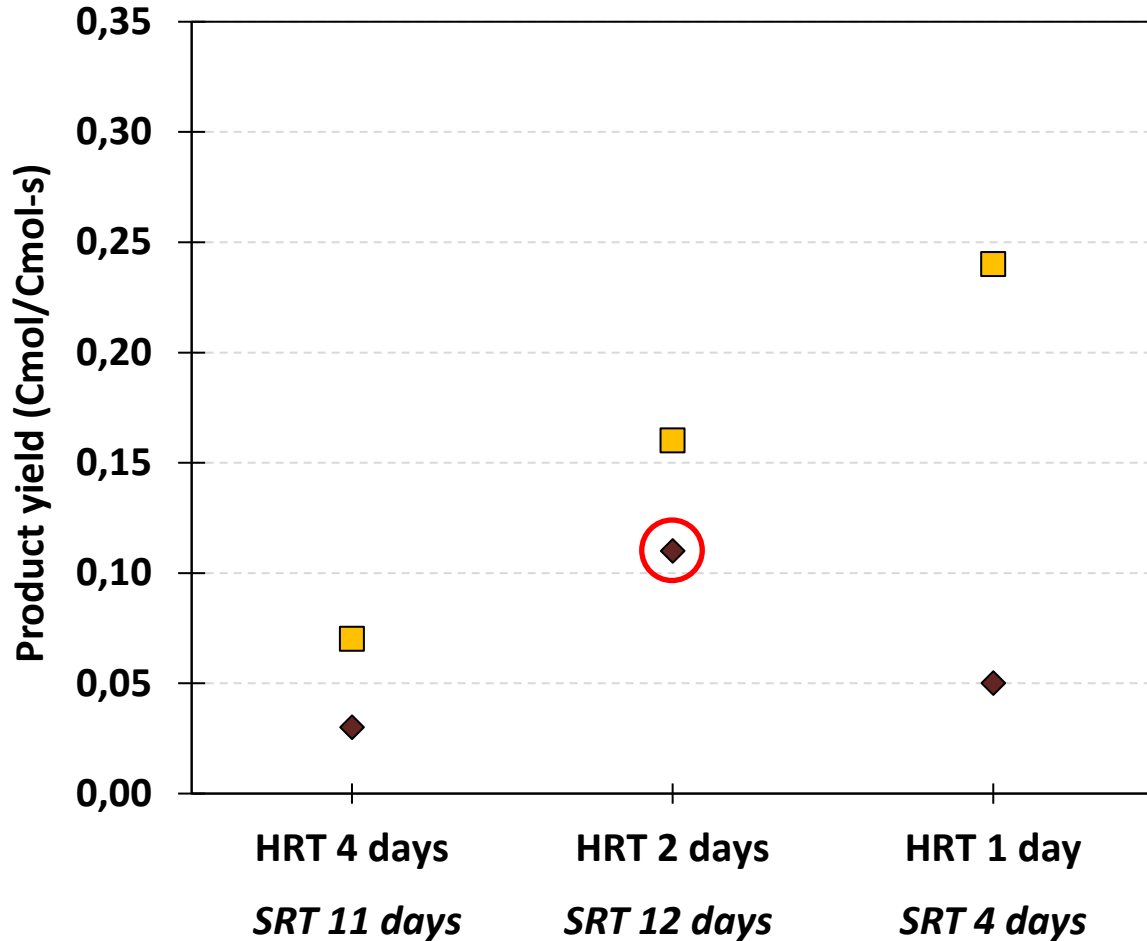
◆ HCa ■ HBU



HCa yield is not directly affected by HRT/SRT value

SBR operation

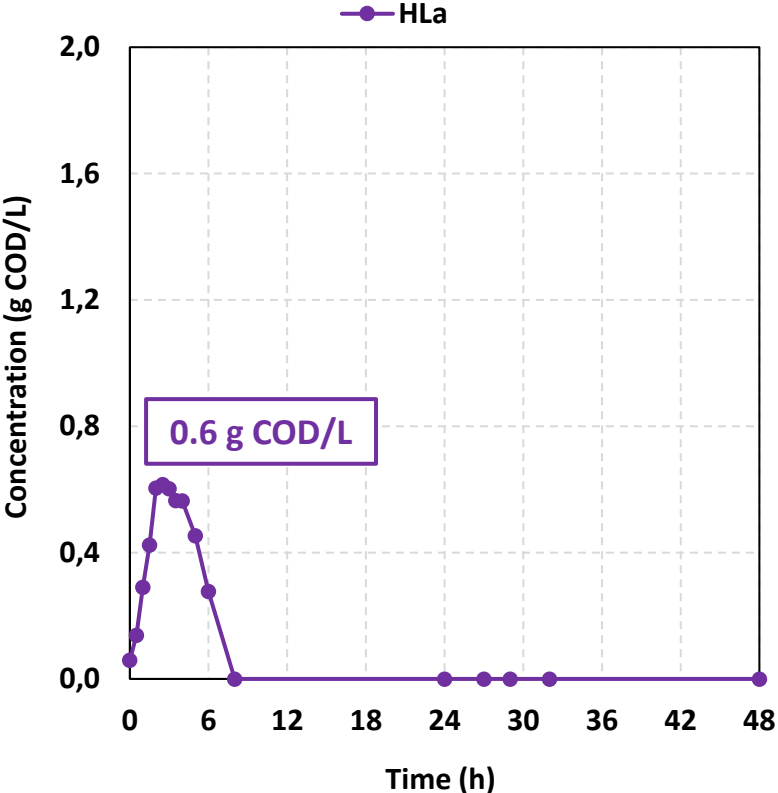
◆ HCa ■ HBu



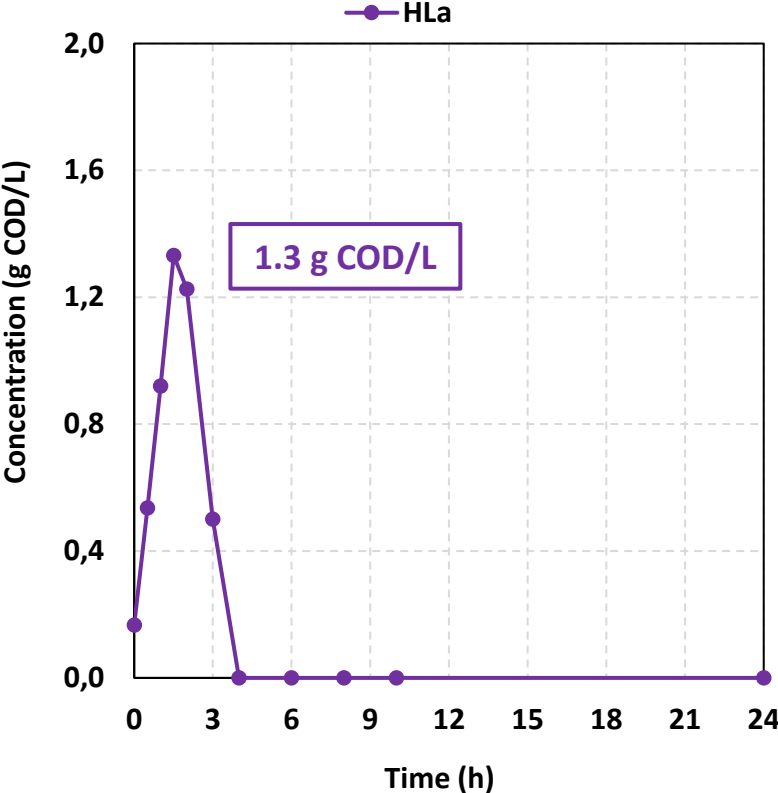
Are the electron donors being produced and converted into HCa? Cycle characterisation

The lower HRT, the higher HLa production

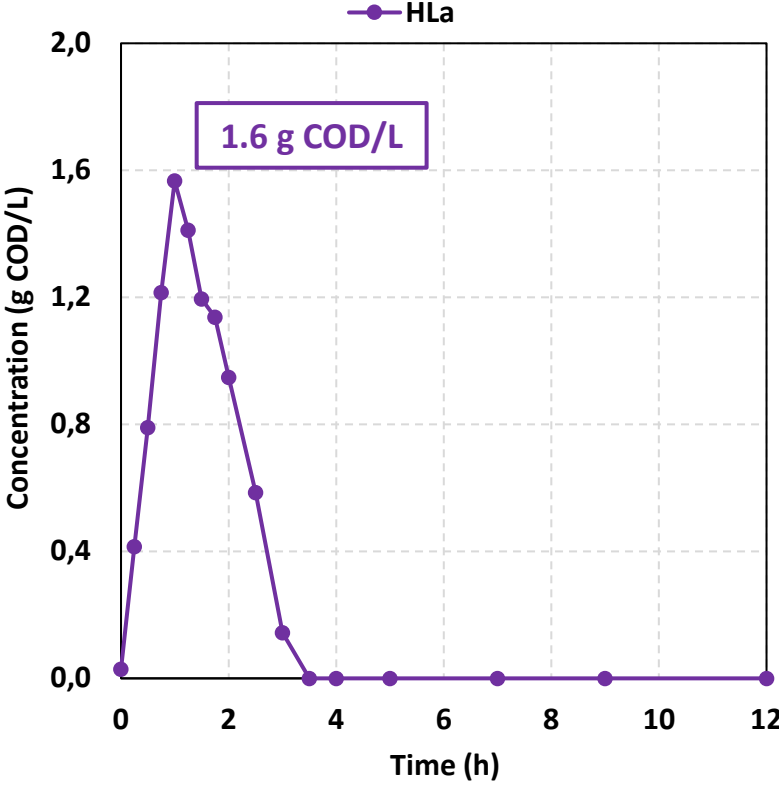
HRT 4 days



HRT 2 days

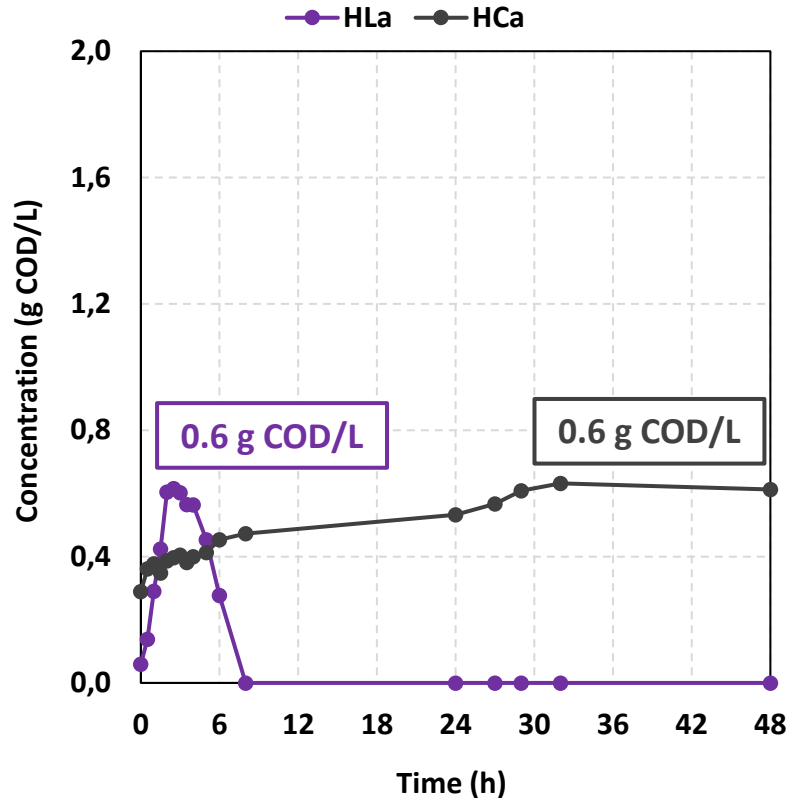


HRT 1 day

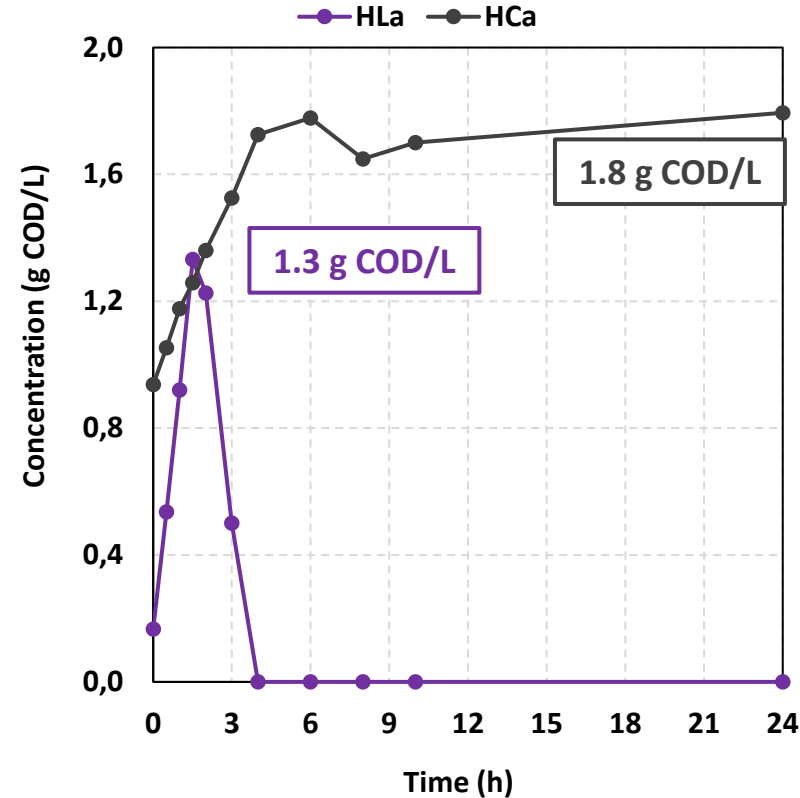


But HCa yield is not linked to the highest HLa production

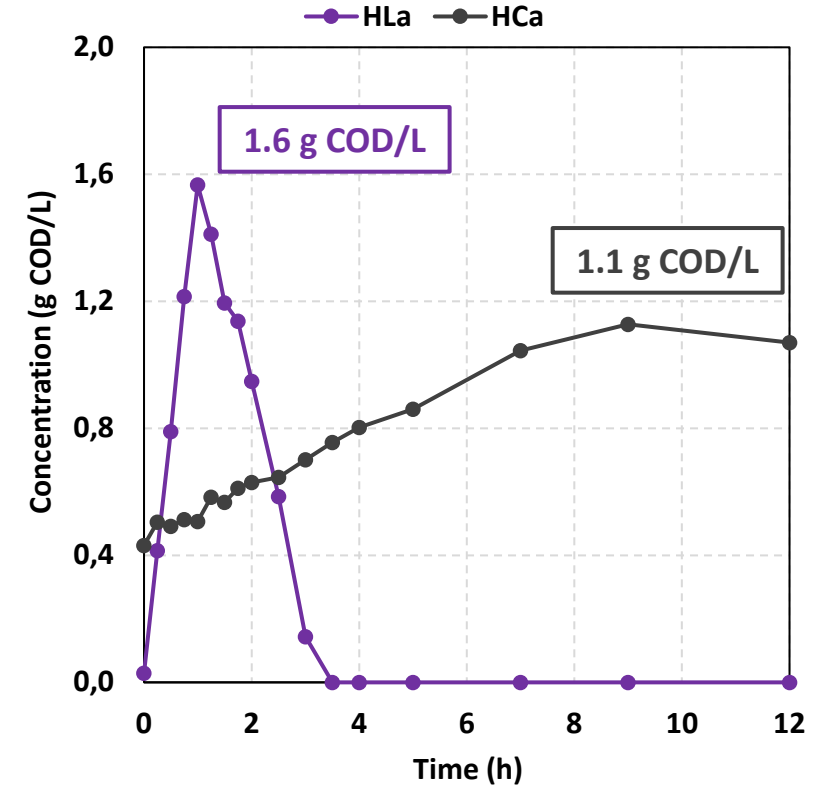
HRT 4 days



HRT 2 days



HRT 1 day



A balance between electron donor availability and caproate selectivity must be found

Take-home messages

- Acidic pH did not limit xylan hydrolysis
- Xylan was always consumed regardless the HRT or reactor configuration
- Chain elongation stage was optimised in SBR mode at HRT 2 days
- Lactic acid availability and/or lactic acid steering towards caproate are the main bottlenecks → ongoing work

Acknowledgements

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Cell
Chem

ERA CoBioTech

CRETUS Cross-disciplinary Research in Environmental Technologies

BioGroup
Group of Environmental Biotechnology

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Thank you for your attention!

Kinetic limitations in xylan conversion to caproate

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