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Valorisation of the organic fraction of Municipal Solid Waste: Improving succinic acid production efficiency by immobilized continuous fermentation

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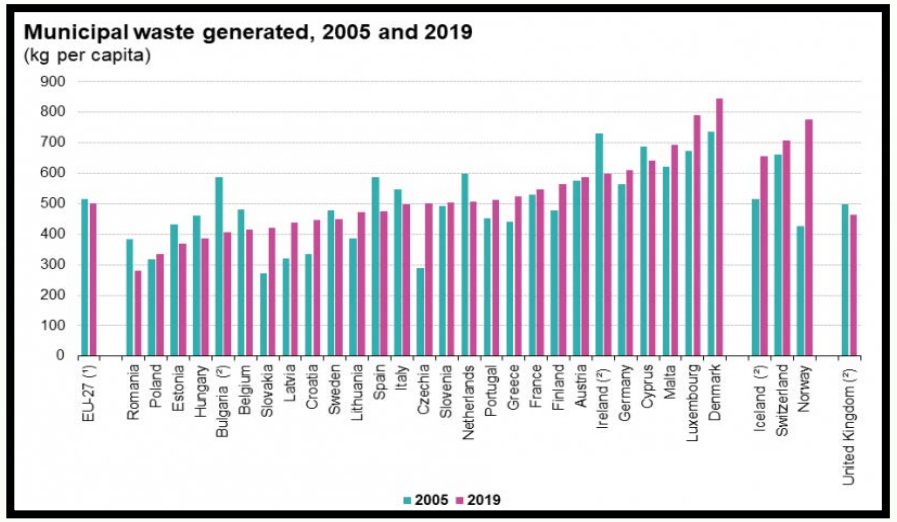
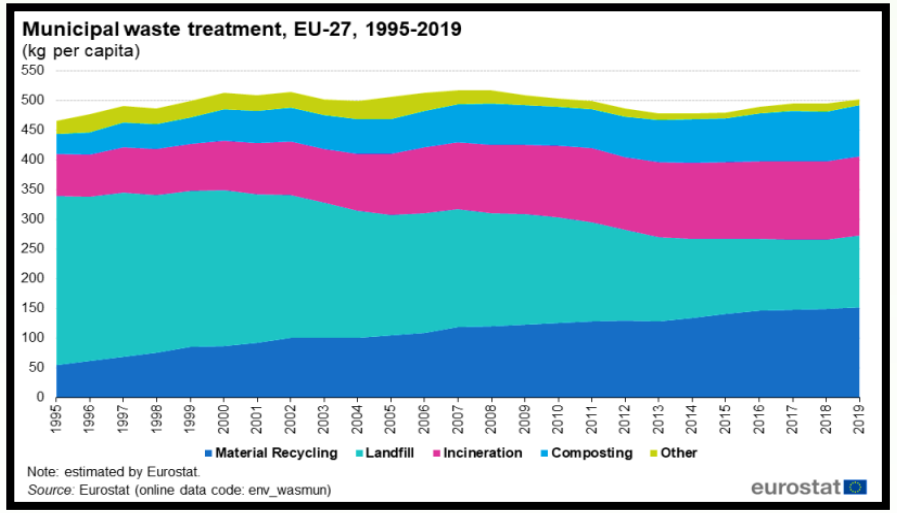
Objectives

- Characterisation of biowaste fraction of municipal solid waste (MSW)
- Valorisation of biowaste fraction of MSW as potential fermentation feedstock for succinic acid production with *Actinobacillus succinogenes*
  - Batch fermentation
  - Fed-batch fermentation
  - Continuous fermentations in a cell free system and immobilised bacterial cells using glucose and OFMSW hydrolysate as carbon source

Municipal solid waste (MSW) in Europe

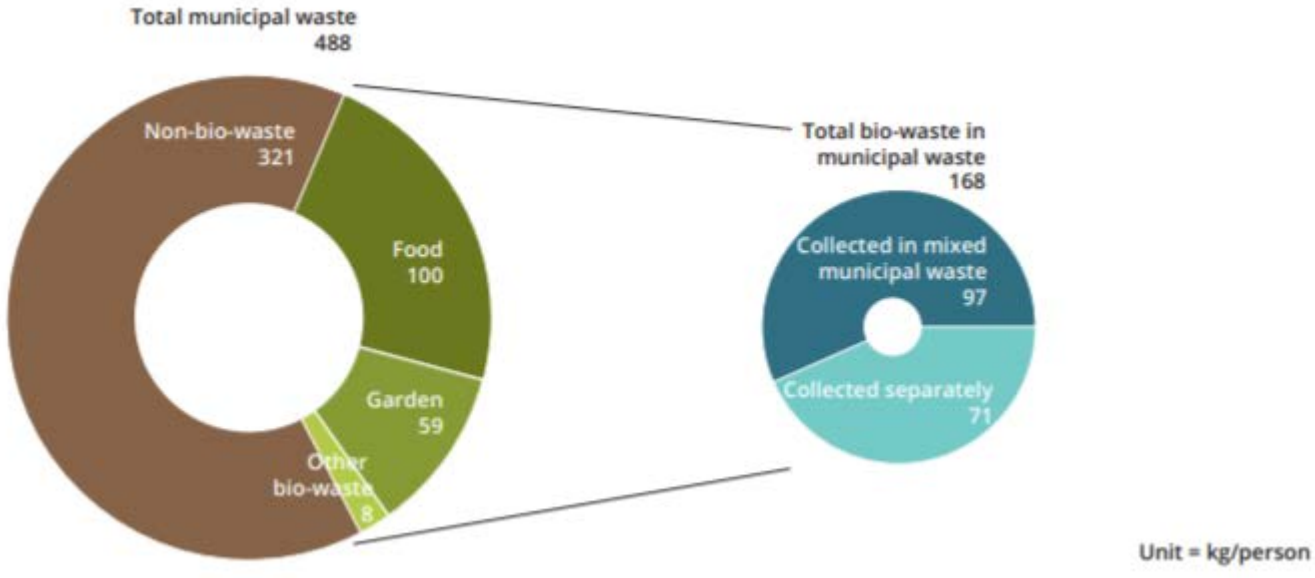
- Municipal solid waste management is an important issue in Europe
- 502 kg of municipal waste per capita were generated in the EU in 2019
- 48% of municipal waste in the EU was recycled in 2019
- The total amount of municipal waste landfilled has diminished
- The landfilling rate in the EU dropped from 61 % (1995) to 23 % (2019)



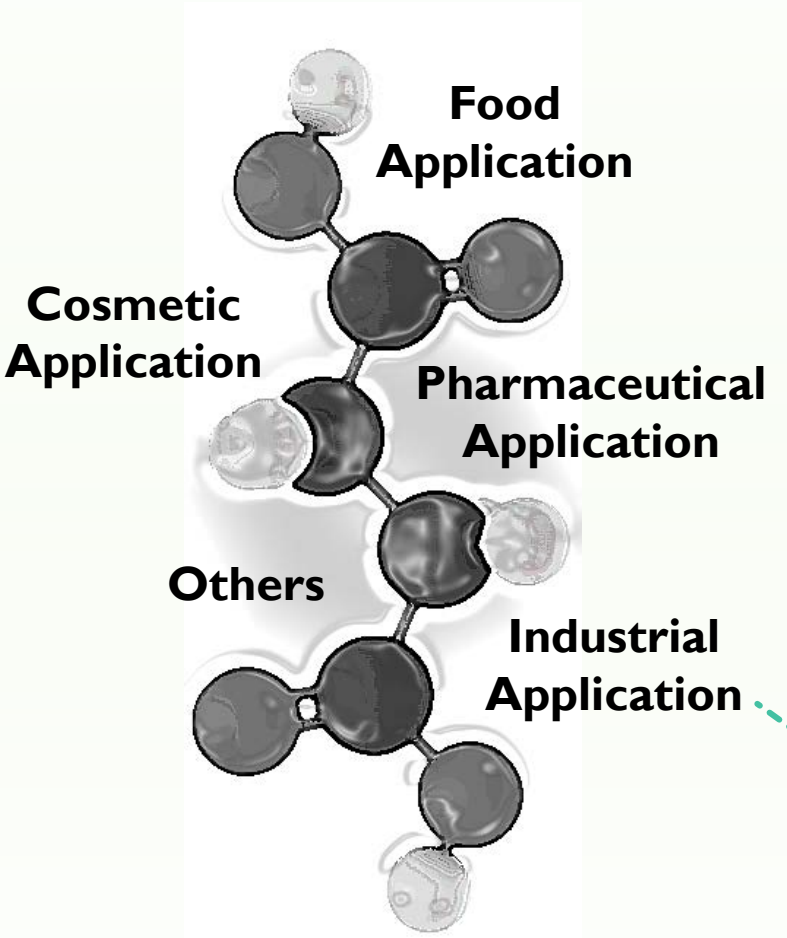


Organic fraction of municipal solid waste (OFMSW) in Europe

- Bio-waste represents an important share of European municipal waste generation
- In 2017, the EU-28 generated 249 million tonnes of municipal solid waste of which about 34 % (86 million tonnes) was the bio-waste fraction
- Total municipal bio-waste in the EU-28 consist of:
  - 60 % Food waste
  - 35 % Garden waste
  - 5 % Other



Potential of succinic acid as platform chemical



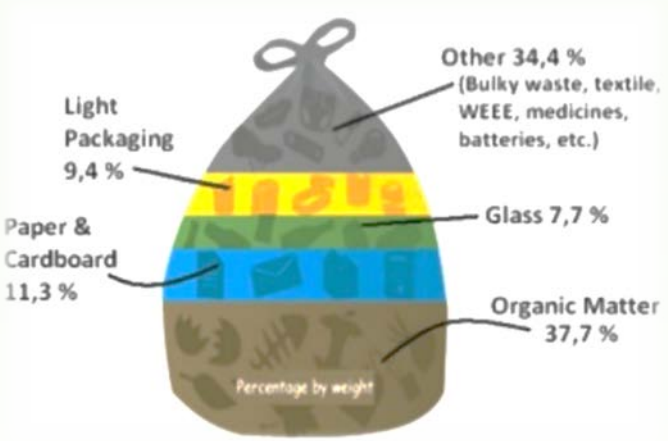
- One of the top 12 value-added bio-based chemicals
- Total succinic acid market demand is estimated around 50,000 metric tonnes in 2016 and is expected to reach 94,000 metric tonnes at the end of 2025 with an annual growth rate of 6.5%
- Intermediate in several chemical processes

- 1,4-Butanediol (BDO) and Derivatives
- Polyesters polyols
- Resins, Coatings, Pigments, & Inks
- Solvents and Lubricants
- Polybutylene succinate (PBS)
- Plasticizers

OFMSW hydrolysate composition

Liquid fraction composition		
Component	Aver	StDev
pH	5.12	0.06
Free amino nitrogen (mg/L)	203.6	0.32
Inorganic phosphorus (mg/L)	100.6	0.55
Total sugars conc. (g/L)	89.9	2.10
Sucrose	1.8	0.10
Glucose	75.9	0.60
Xylose	7.6	0.40
Galactose	1.4	0.50
Arabinose	0.5	0.40
Mannose	0.0-0.5	
Fructose	0.0-0.5	
Glycerol	2.0	0.60
Organic acids (g/L)	13.2	2.00
Lactic acid	10.7	2.00
Acetic acid	2.9	0.02

Solid fraction composition		
Component	Aver	StDev
Total dry weight of suspension (g/L)	114.2	
Moisture content of centrifuged solids (%)	54.3	0.41
Ash content (% dry basis)	25.0	0.60
Lipid content (% dry basis)	7.3	0.60
Protein content (% dry basis)	8.4	0.02



Experimental design
Batch and Fed-batch fermentations

Bacterial strain:

Actinobacillus succinogenes 130Z

Fermentation conditions:

Fermentation volume: 500 mL

Temperature: 37 ° C

Agitation: 100 rpm

pH: 6.7

CO_2 flow : 0.5 L/min

Batch fermentations

OFMSW hydrolysate as carbon source → Effect of initial carbon source concentration → 30, 50 and 80 g/L total carbon source concentration

Fed-batch fermentations

OFMSW hydrolysate as carbon source → Initial $MgCO_3$ concentration → 5, 10 and 20 g/L $MgCO_3$

OFMSW hydrolysate as carbon source → Nitrogen source → 5g/L YE; 5g/L Corn steep liquor

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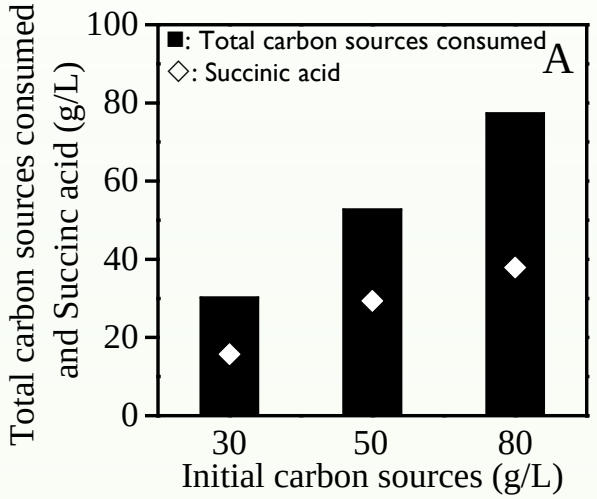
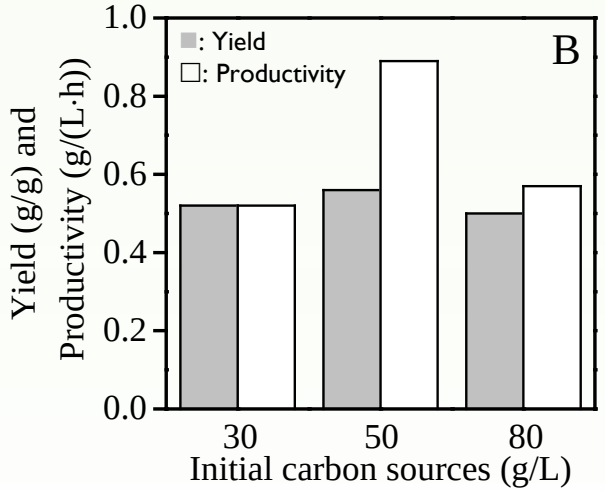
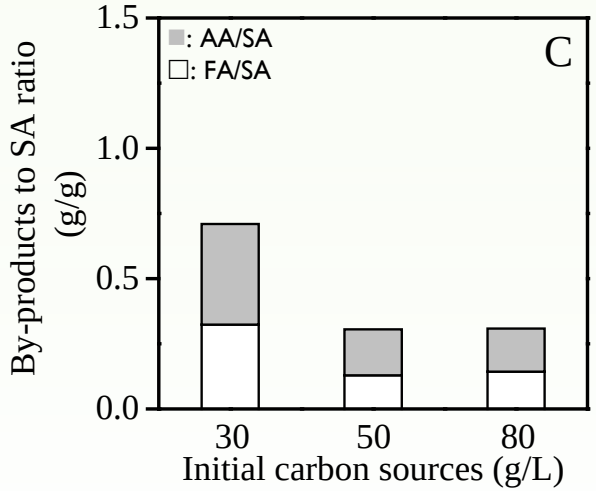
Batch fermentations using OFMSW hydrolysate

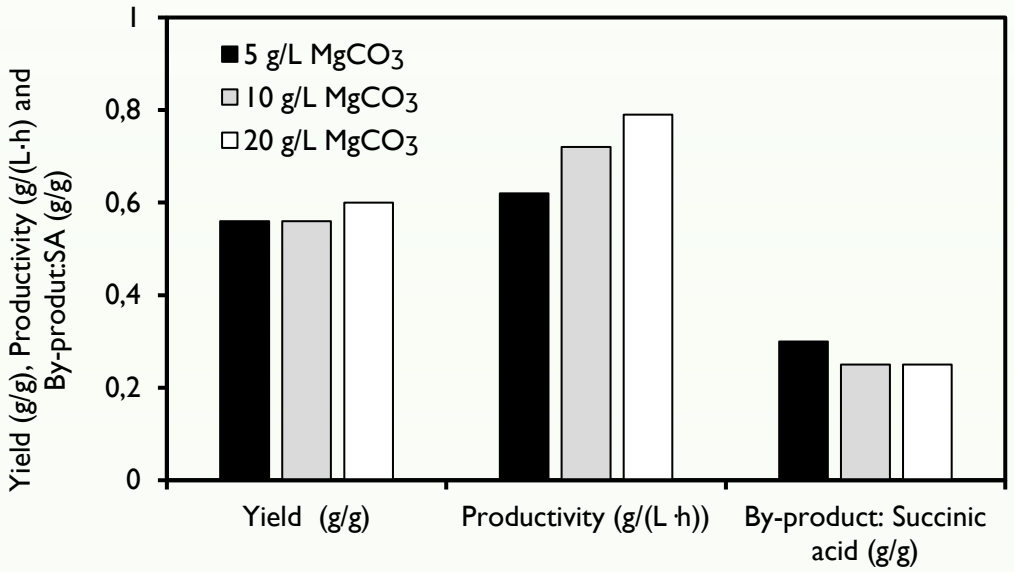
- OFMSW hydrolysate can efficiently used as fermentation feedstock for succinic acid production
- The total by-products to succinic acid ratio was decreased with increasing the initial total carbon source concentration
- Highest yield and productivity was observed at 50 g/L initial carbon source concentration

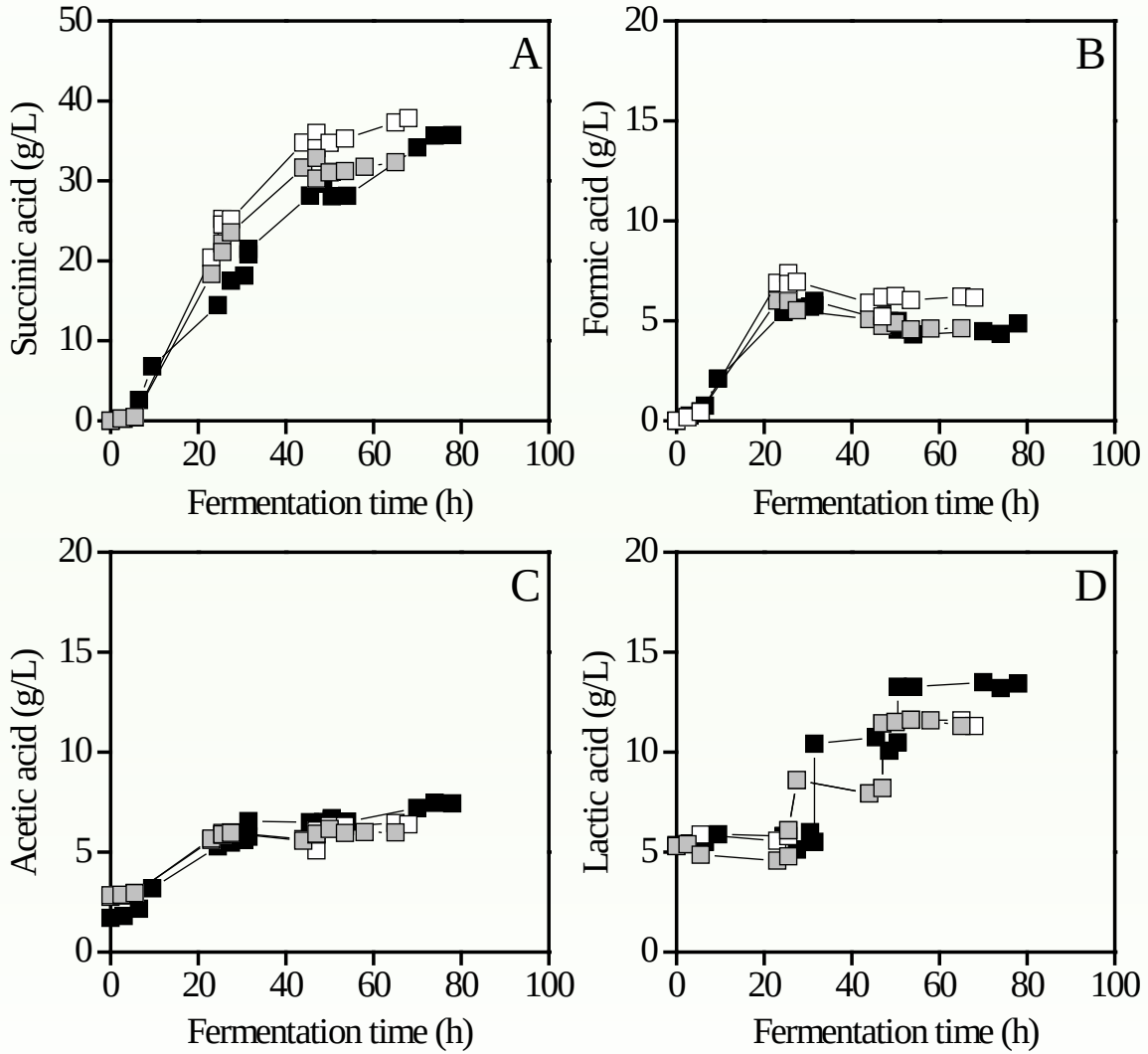






Fed-batch fermentations
Initial $MgCO_3$ concentrations

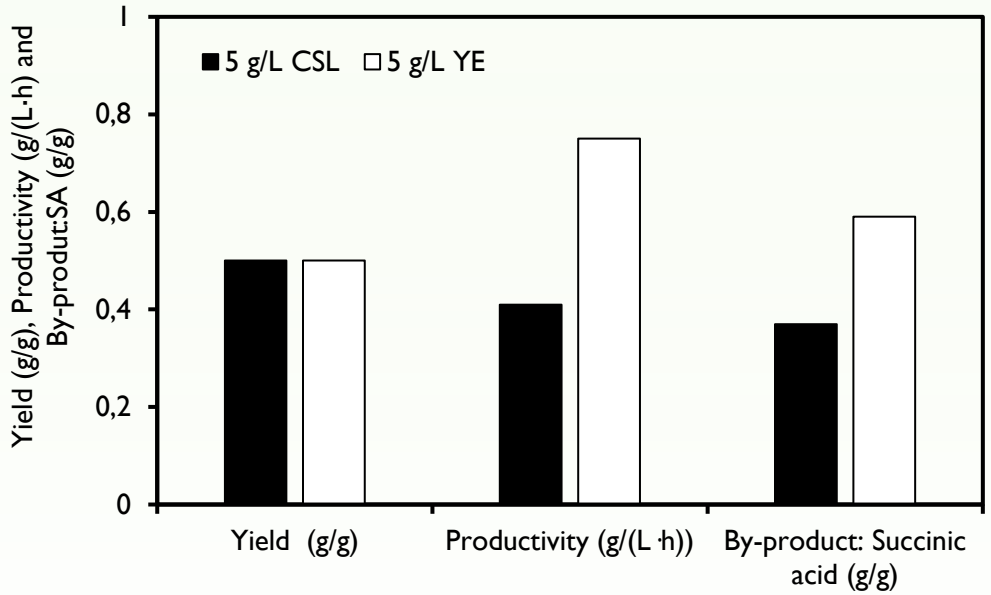


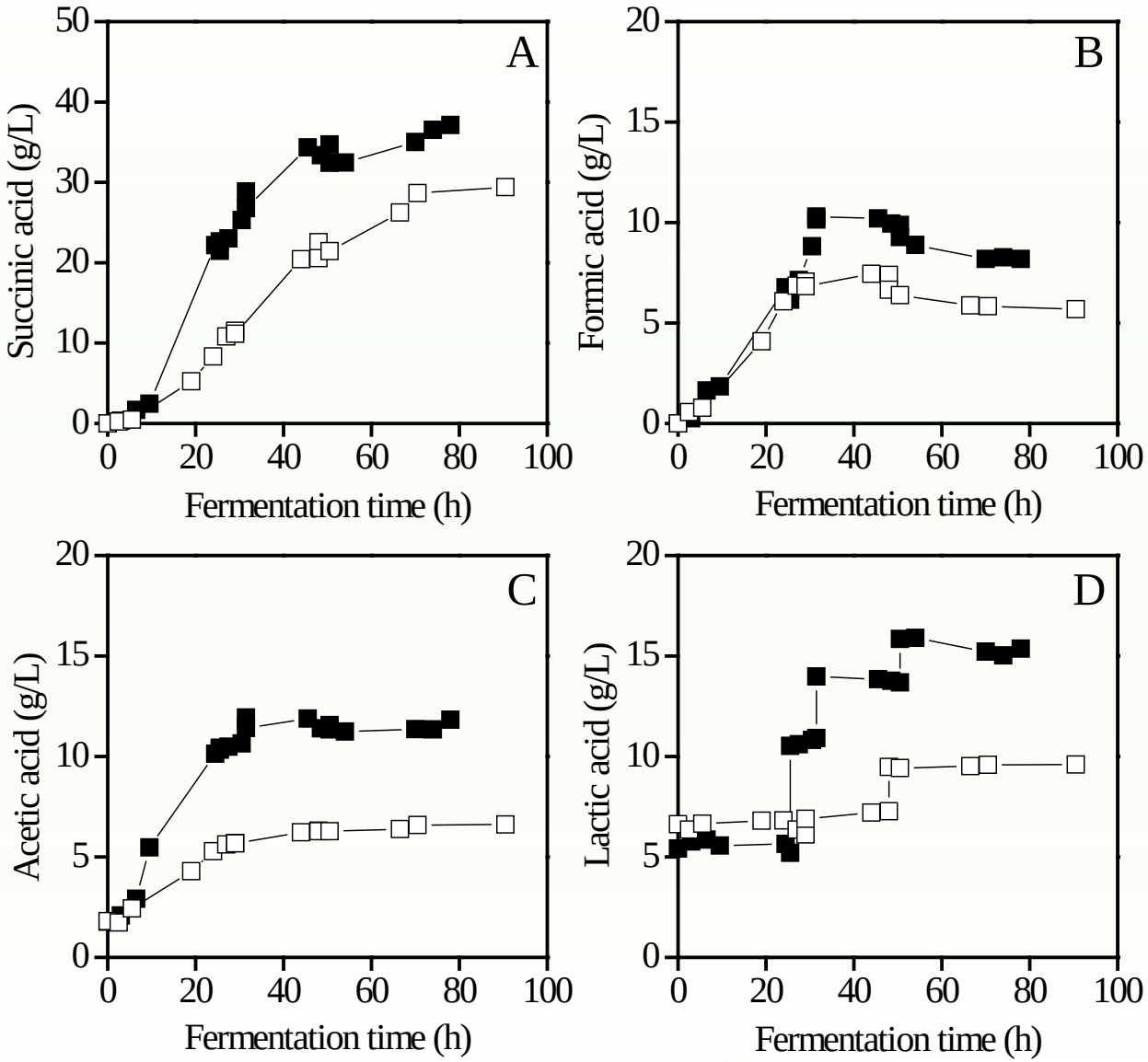


- Succinic acid production improved with increasing $MgCO_3$ concentration
- No significant differences were observed in By-product:SA ratio

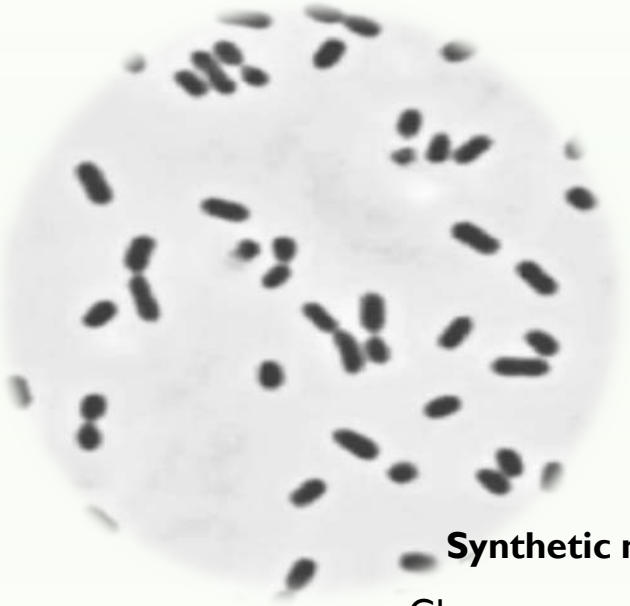
Fed-batch fermentations Nitrogen source

- Supplemented the hydrolysate with 5 g/L YE resulted in significant higher succinic acid production of 37 g/L





Experimental design
Continuous fermentation



Bacterial strain:

Actinobacillus succinogenes 130Z

Synthetic medium:

Glucose as carbon source

Yeast extract: 5g/L

Minerals solution

Fermentation conditions:

Fermentation volume: 500 mL

Temperature: 37 ° C

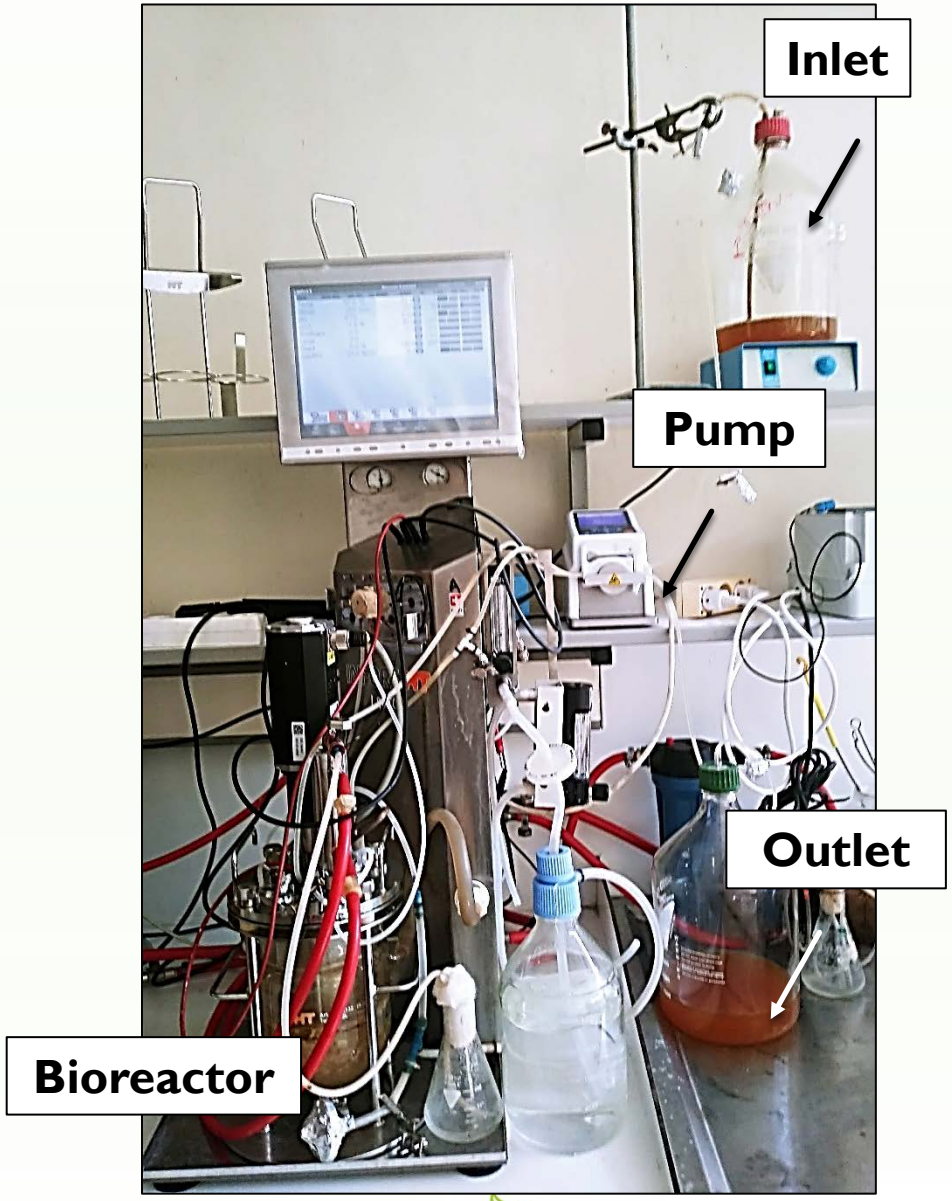
Agitation: 100 rpm

pH: 6.7

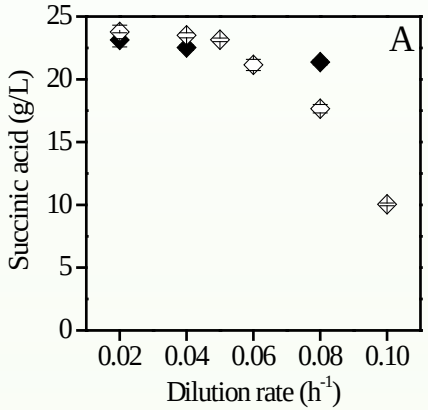
CO_2 flow : 0.5 L/min

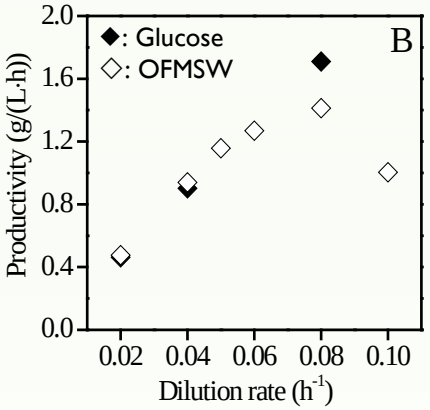
OFMSW hydrolysate:

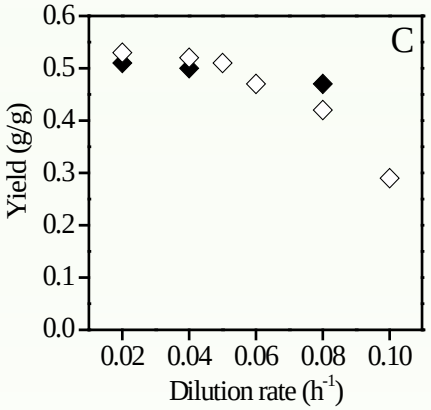
Yeast extract: adjust the Free Amino Nitrogen at 500 mg/L

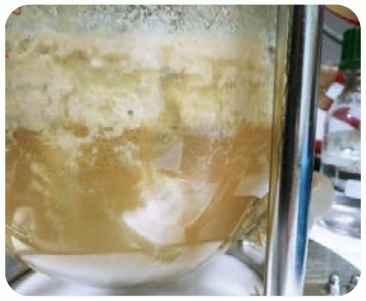


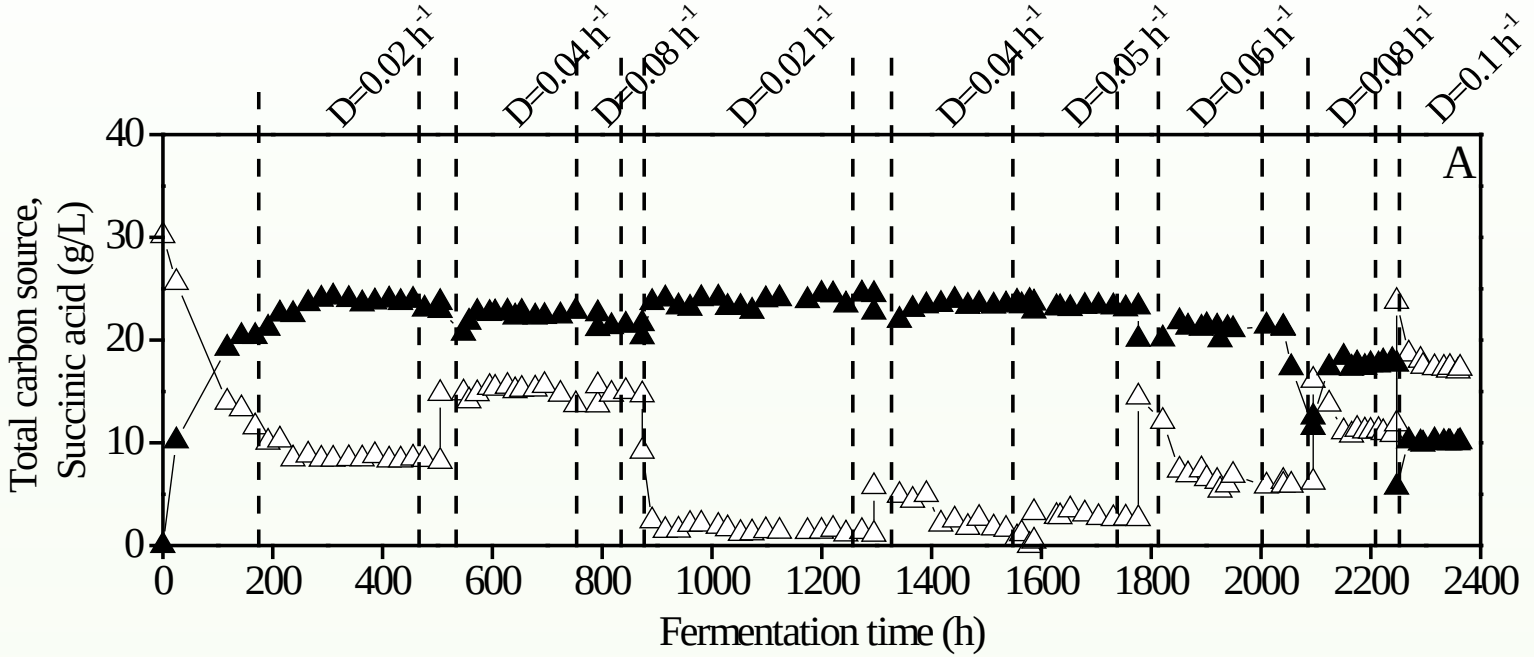
Continuous fermentation

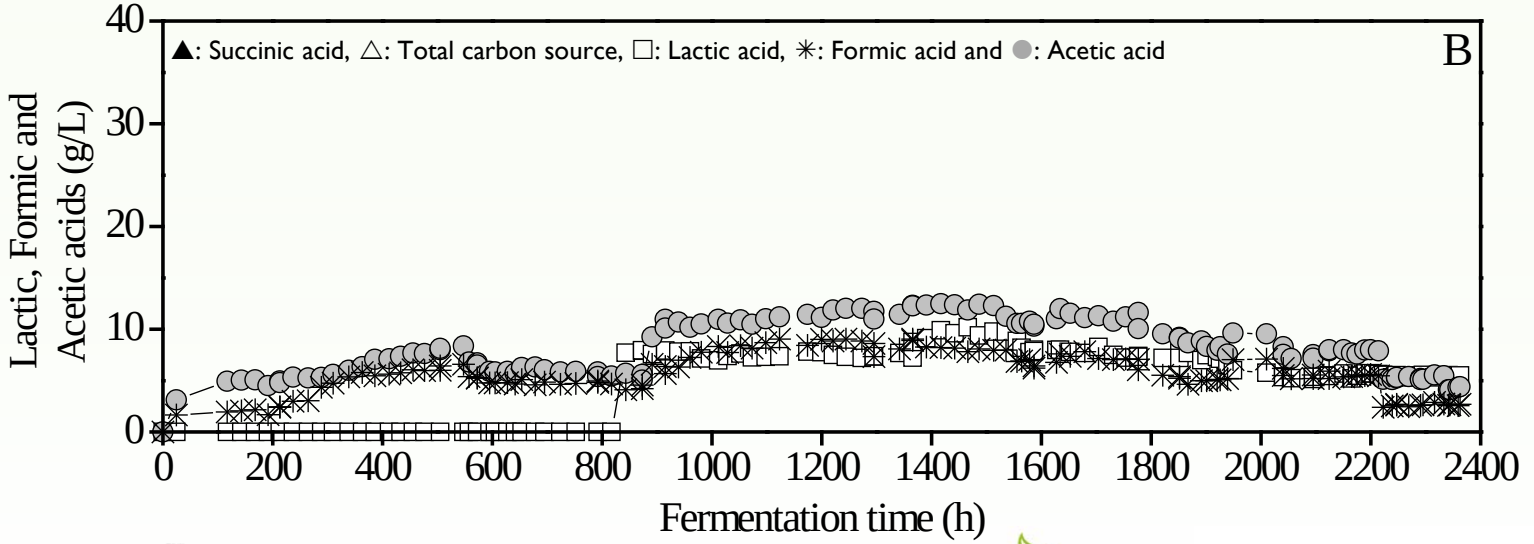












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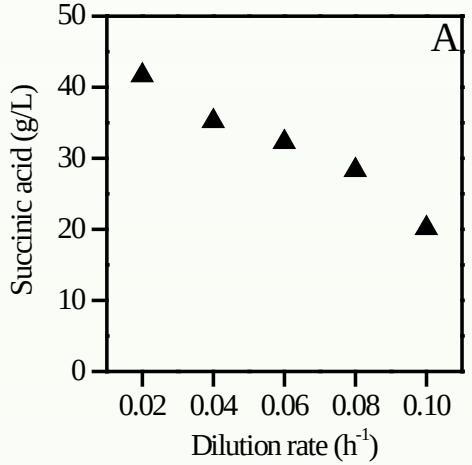
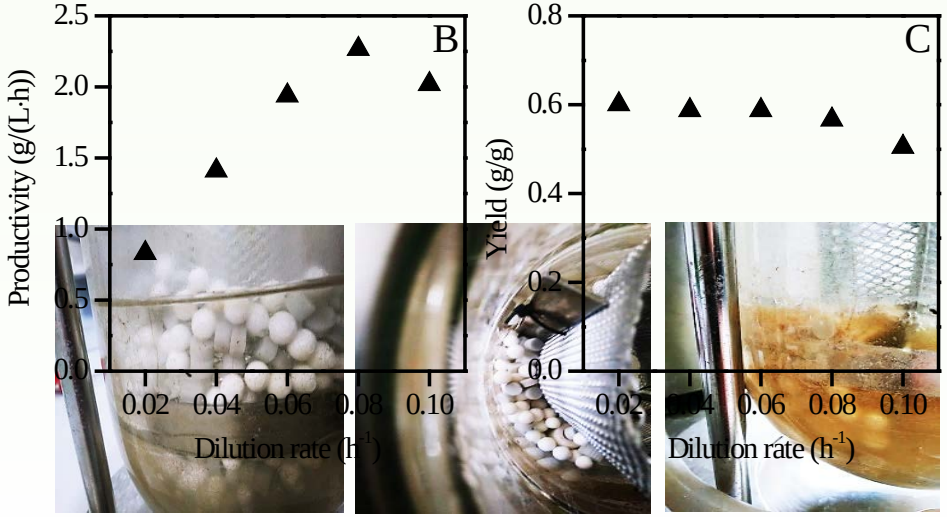
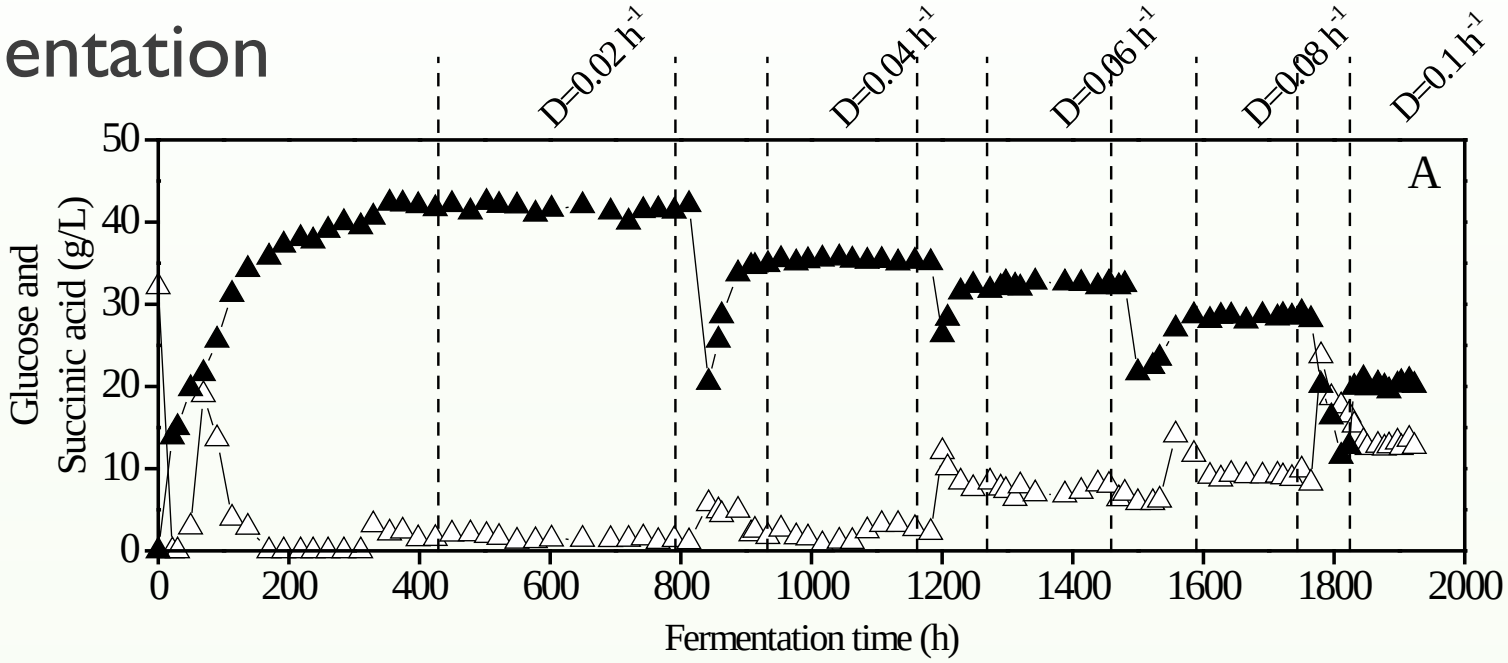
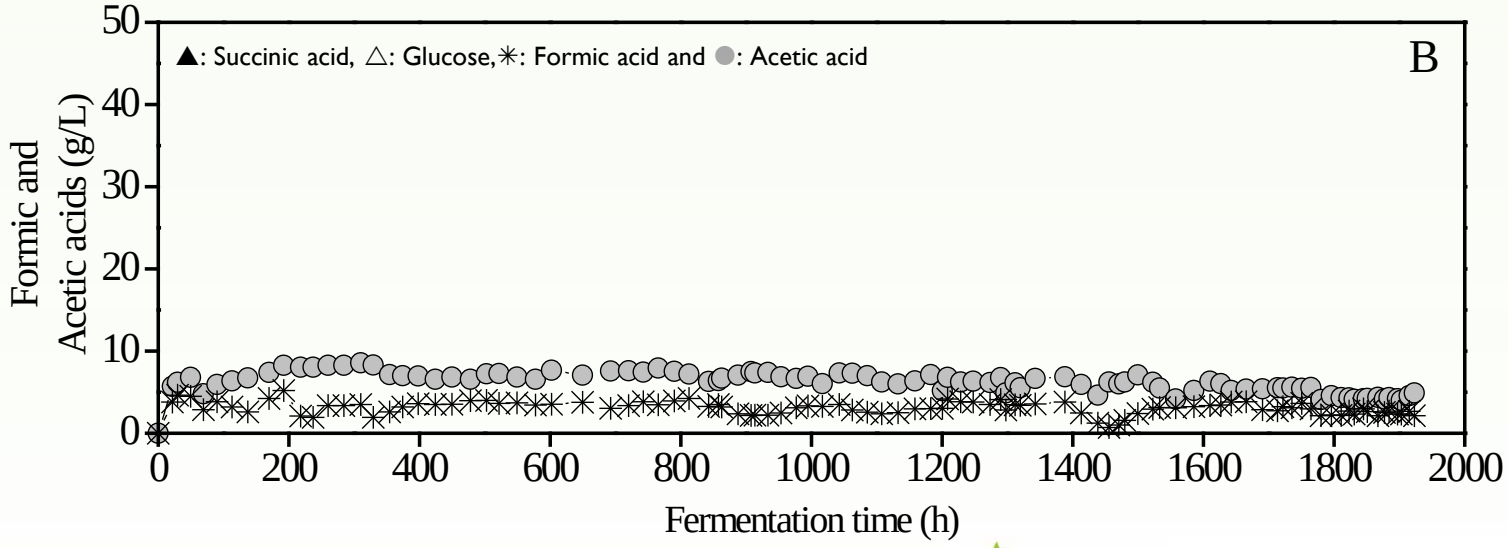
Glucose as carbon source









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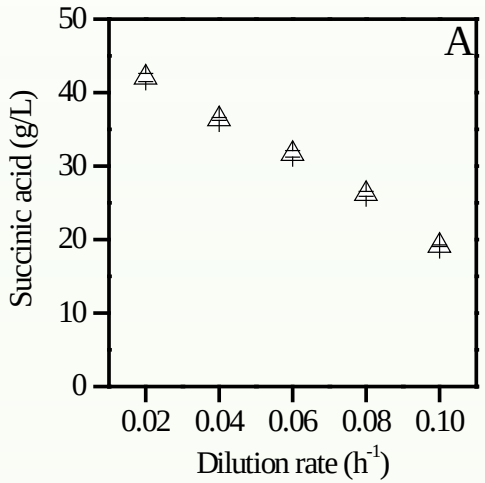
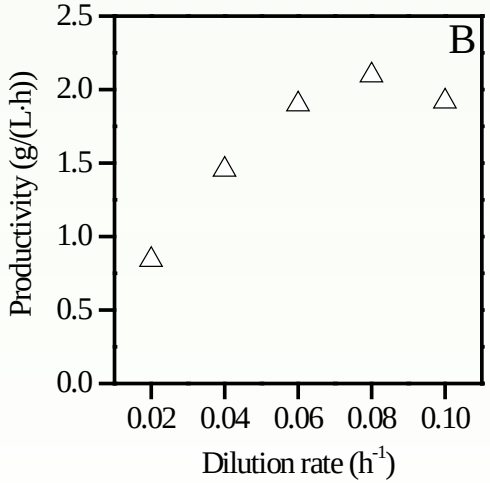
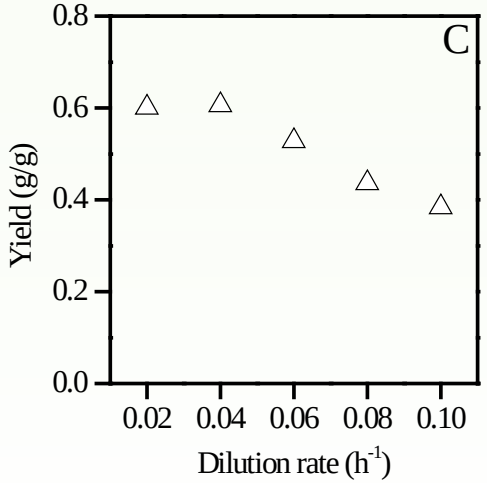
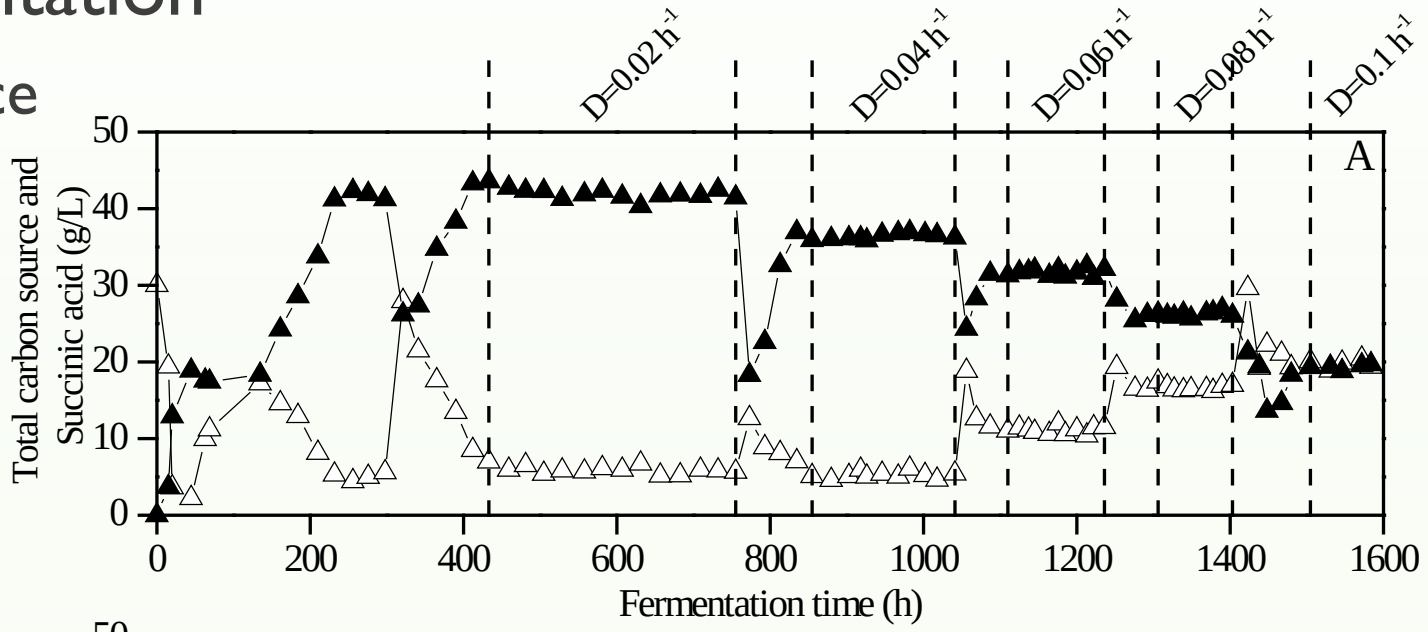
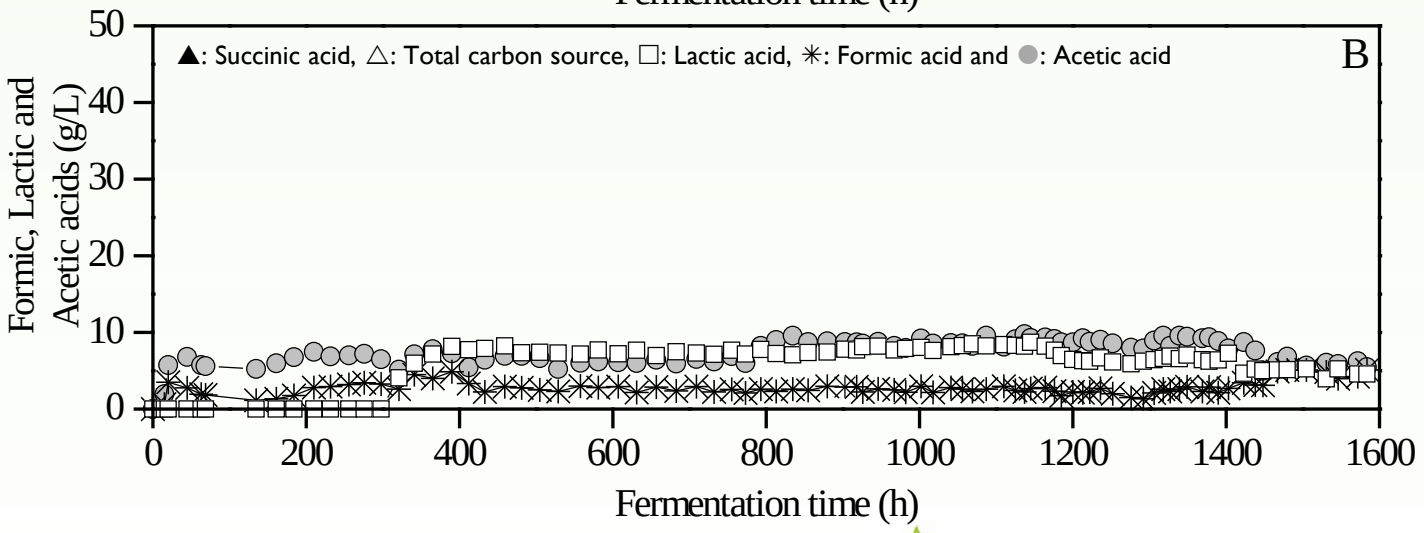
OFMSW hydrolysate as carbon source











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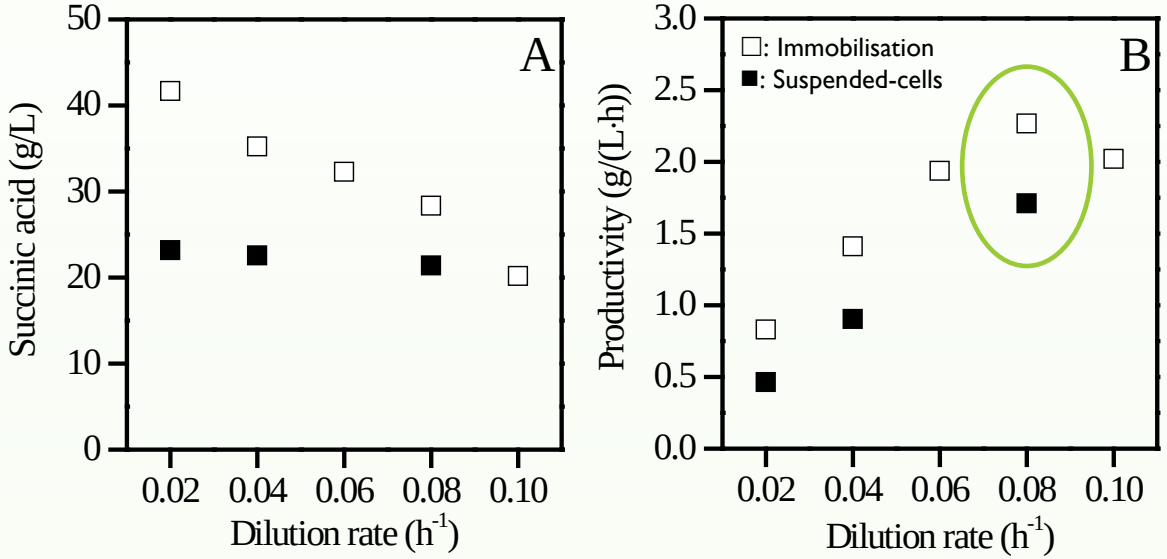
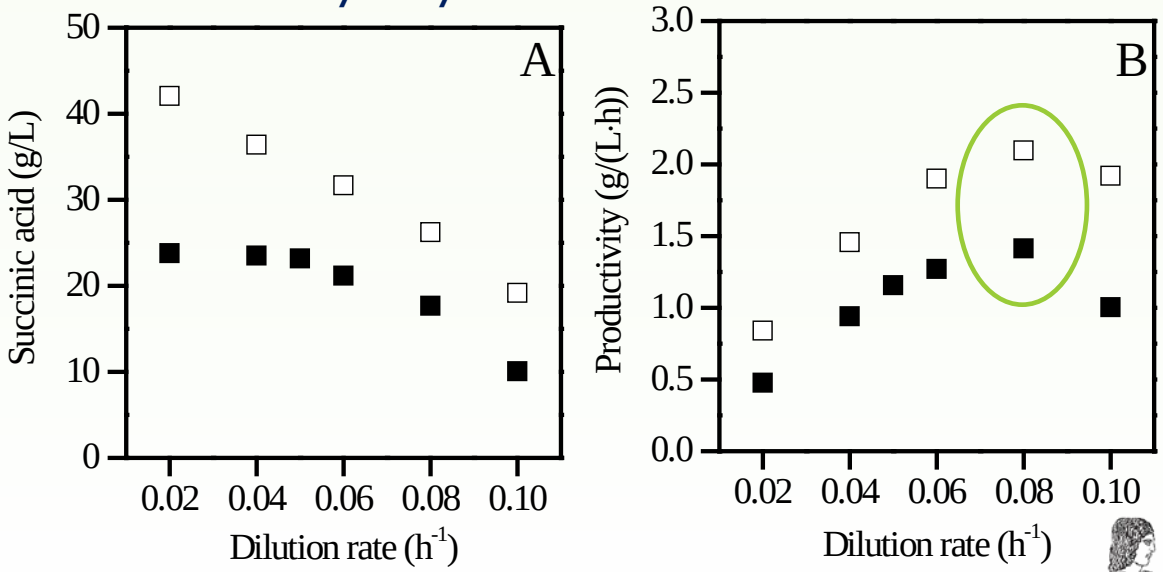
Glucose as carbon source



OFMSW hydrolysate as carbon source



Immobilisation of the culture under continuous operation resulted in higher productivities and final succinic acid concentration at all dilution rates

- The productivity increased by 32.8 % in glucose-based medium at a dilution rate of 0.08 h^{-1}, where succinic acid concentration was 28.3 g/L
- When OFMSW hydrolysate was used as feeding solution the productivity increased by 22.8 % with succinic acid concentration of 26.2 g/L at a dilution rate of 0.08 h^{-1}

Conclusions

- The OFMSW hydrolysate can be considered as a promising feedstock for the production of bio-based products via fermentation
- OFMSW could replace commercial nutrients currently used for the production of fermentation products
- *A. succinogenes* 130Z proved to be a natural biofilm former
- The use of immobilized cells in continuous cultures could further improve the biotechnological production of succinic acid

THANK YOU FOR YOUR ATTENTION!

PERCAL Project "Chemical Building Blocks From Versatile MSW Biorefinery"

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