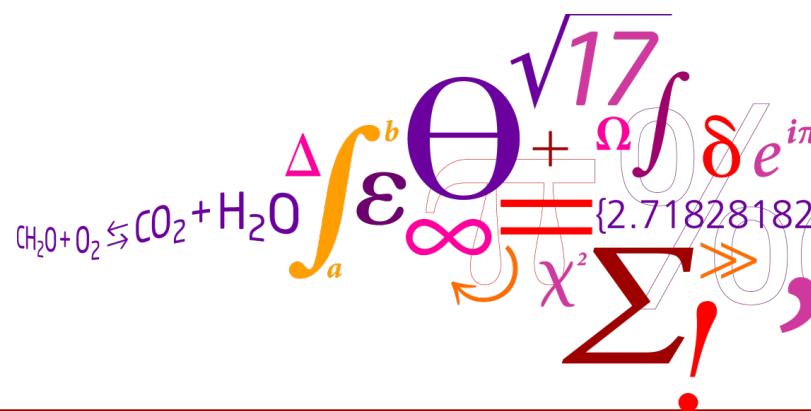


Bioengineering as a tools for upcycling of wastes and residues in an bioeconomy approach

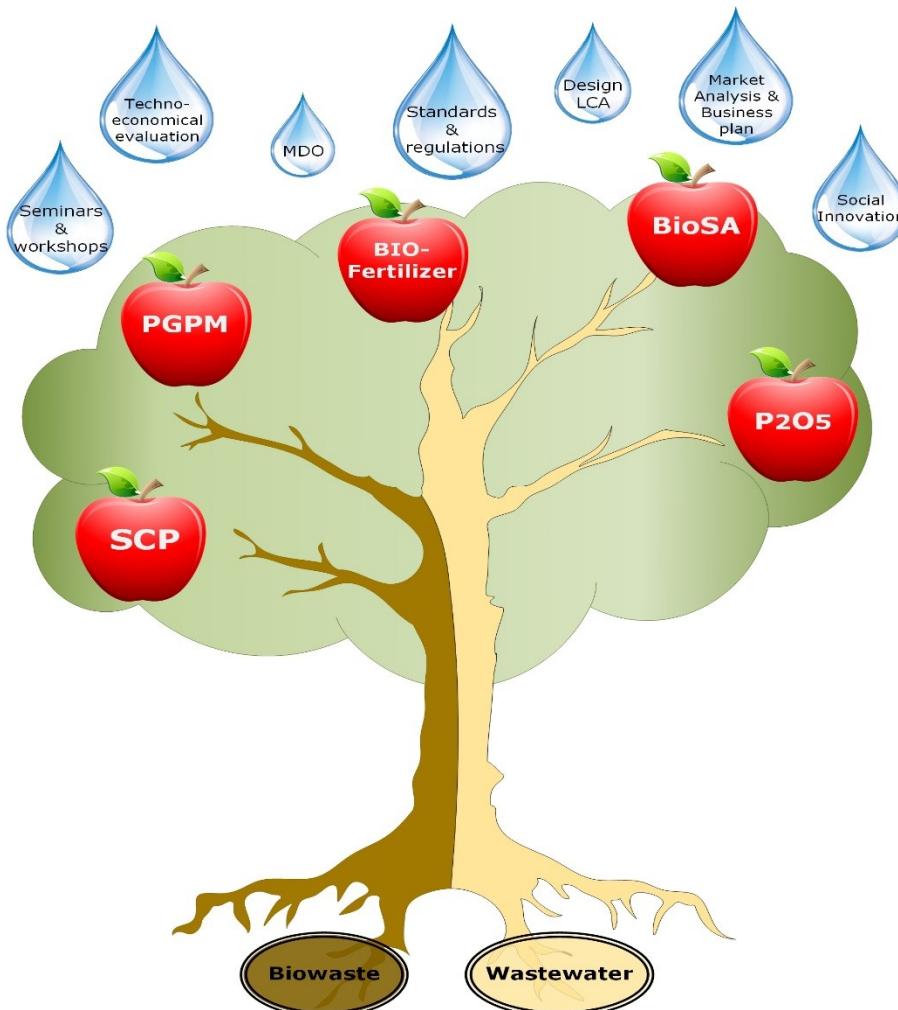
Irini Angelidaki

$$\text{CH}_2\text{O} + \text{O}_2 \xrightarrow{\Delta} \text{CO}_2 + \text{H}_2\text{O}$$


Sustainability?



The Vision - Bioeconomy



CO-CREATE COPENHAGEN

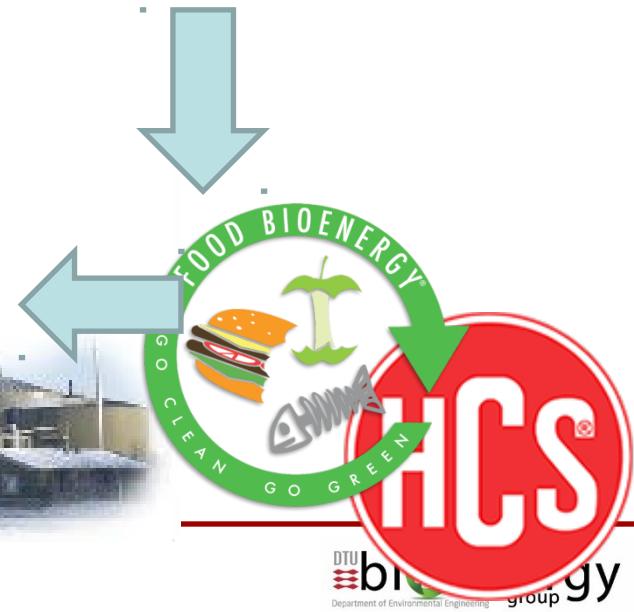
A RESPONSIBLE CITY



270.000 households sort biowaste from 2017



H
BIOGAS
SHØJ



Urban biowaste - Copenhagen



Source sorted household waste

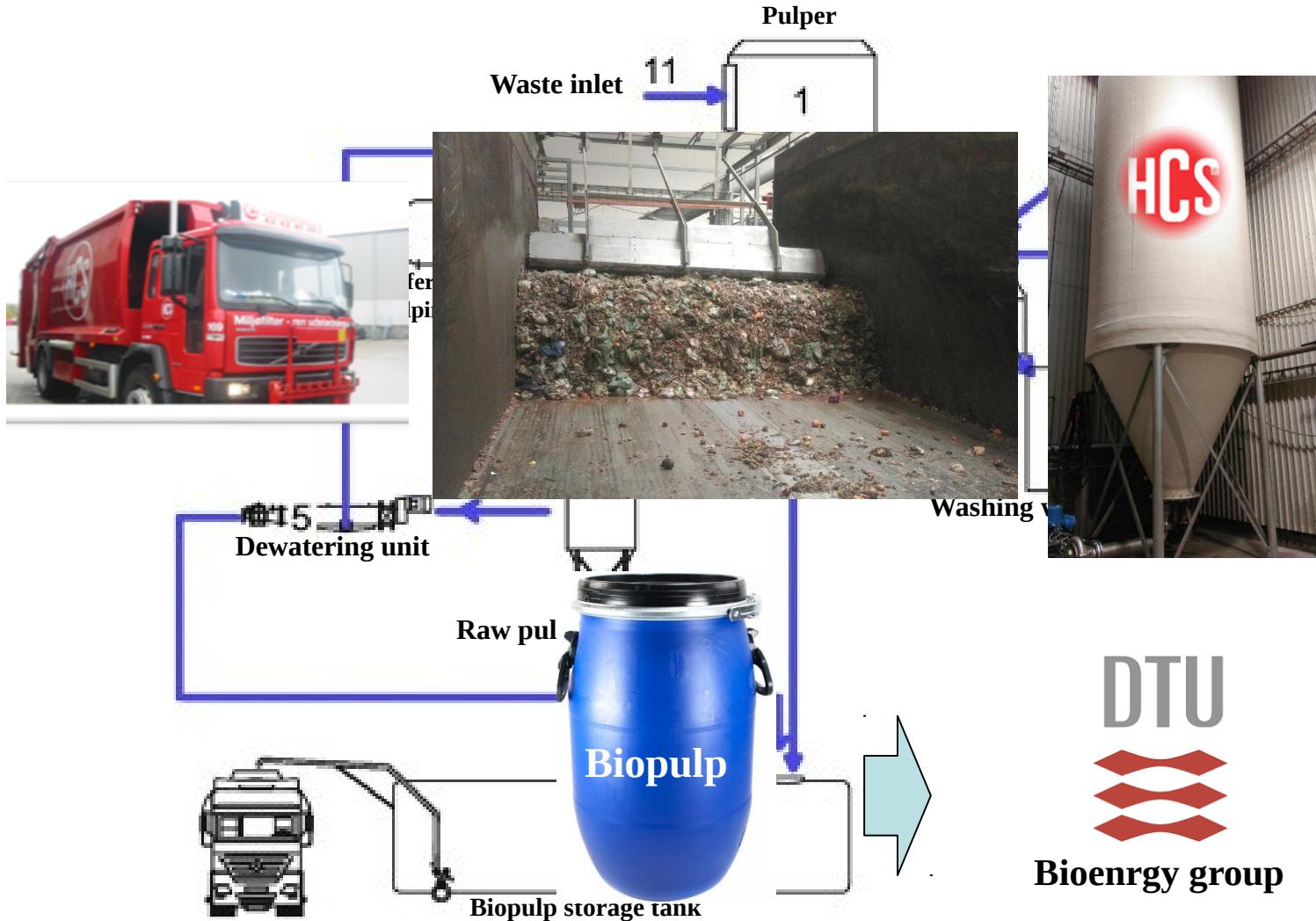


Organic waste from industries



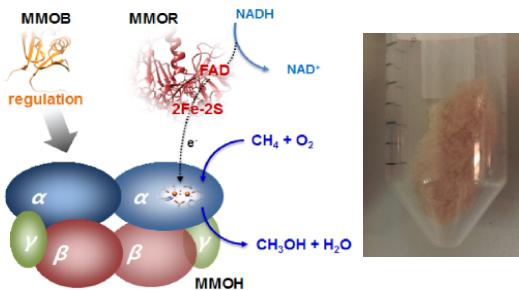
Biopulping technology

Biopulping technology



DTU
Bioenergy group

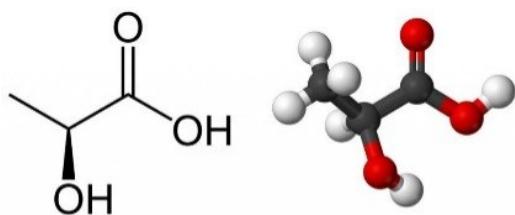
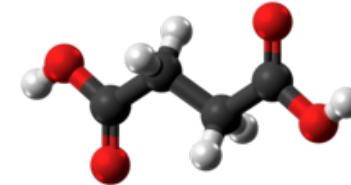
Valorizing urban bio-waste from Copenhagen



1: Single cell protein



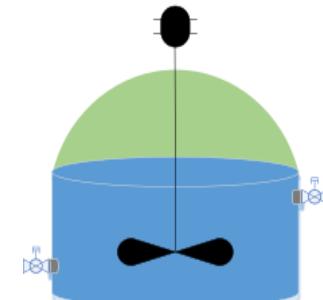
2: BioSuccinic acid



3: Lactic acid

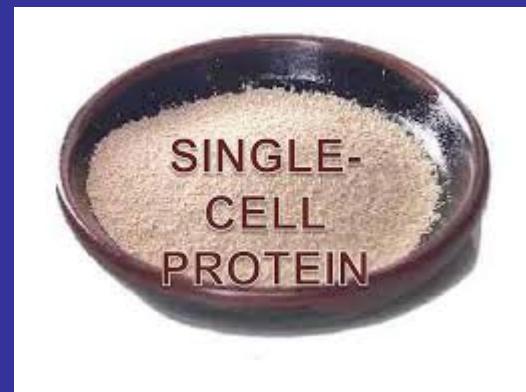


Biopulp



4: Biomethane

1) Single Cell Protein (SCP)



Demand for edible protein

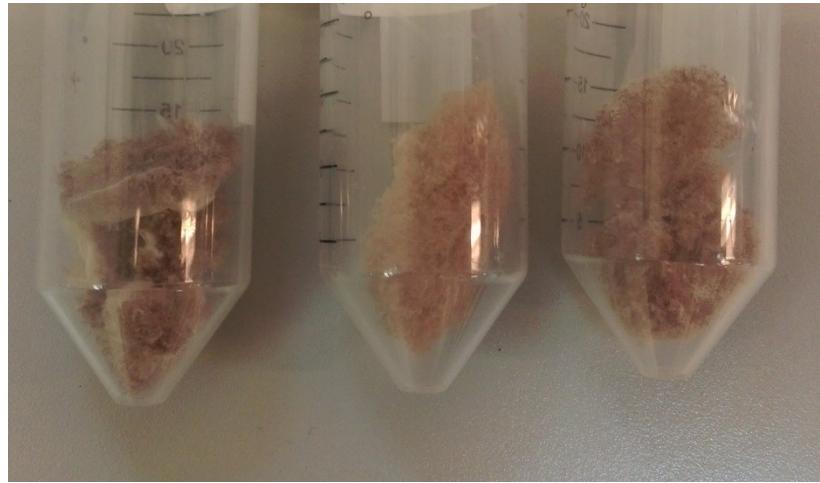
- 100 g of edible protein per person per day
- Protein mainly comes from plant protein (soya)
- World agricultural soils are limited.
- Other sources for protein? Microbial protein (SCP)



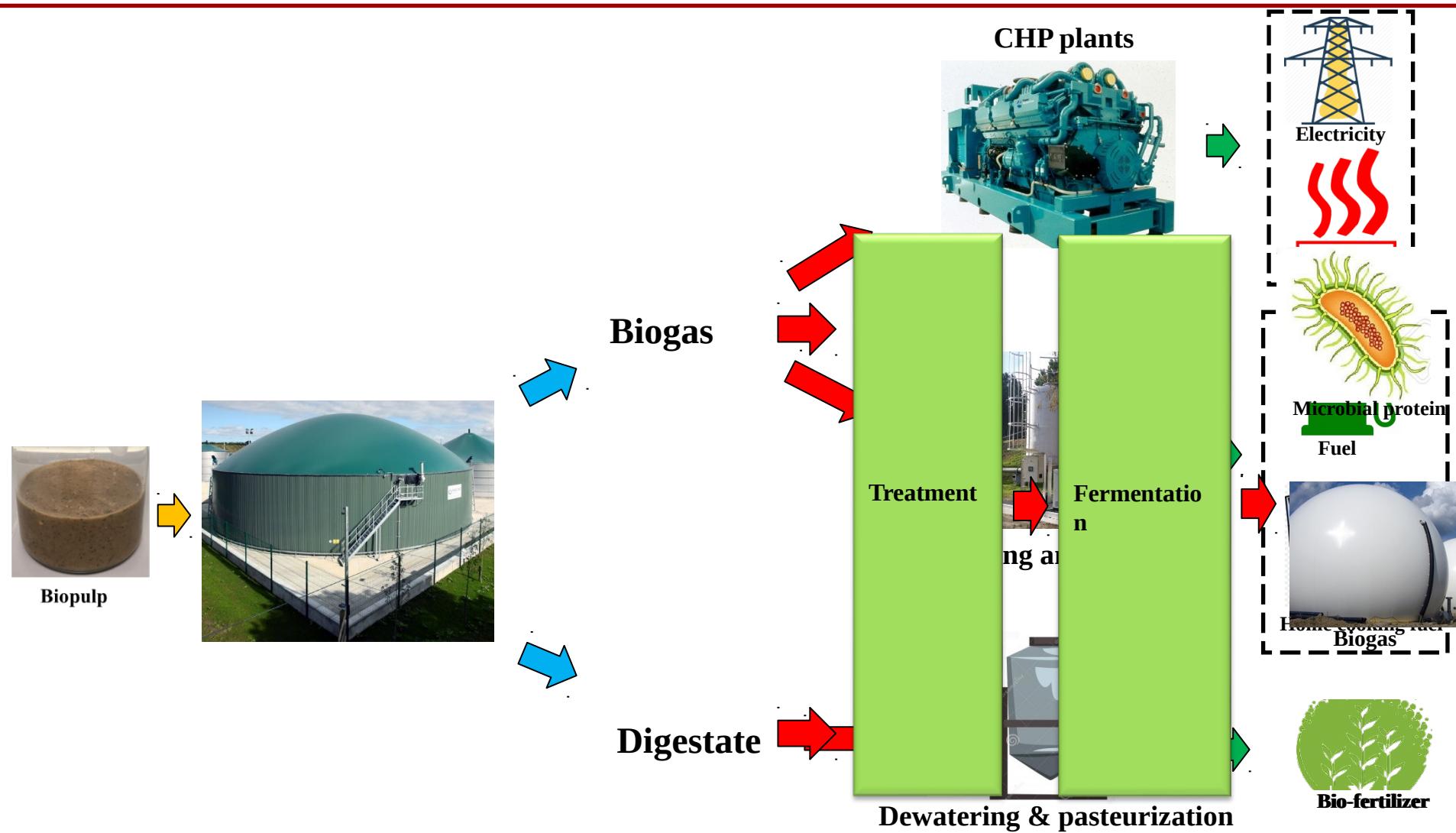
got protein?

Single cell Protein

- SCP refers to edible unicellular microorganisms which contain protein.
- Protein can be extracted from pure or mixed cultures of algae, yeasts, fungi or bacteria.
- The biomass produced can substitute protein rich foods.
- It is suitable for human consumption or as animal feeds.

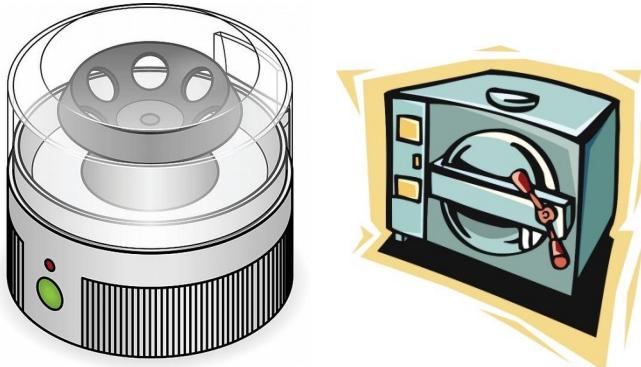


Single cell Protein production



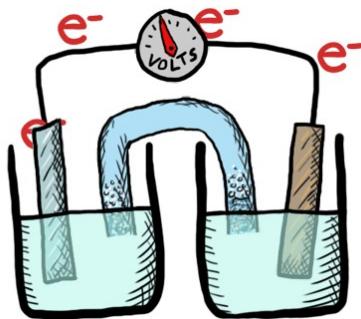
Digestate treatment for SCP production

Centrifuge pasteurize system



Liquid fraction used to cultivate SCP

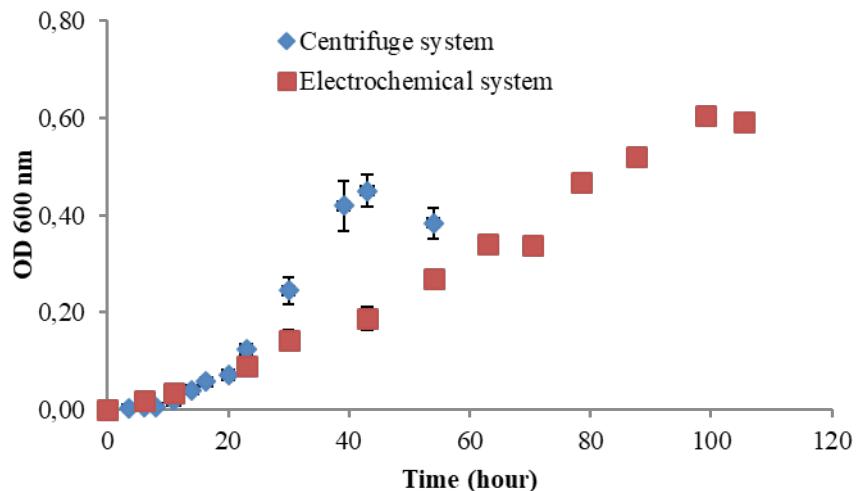
Digestate



Extracted ammonium supplemented with trace elements used to cultivate SCP

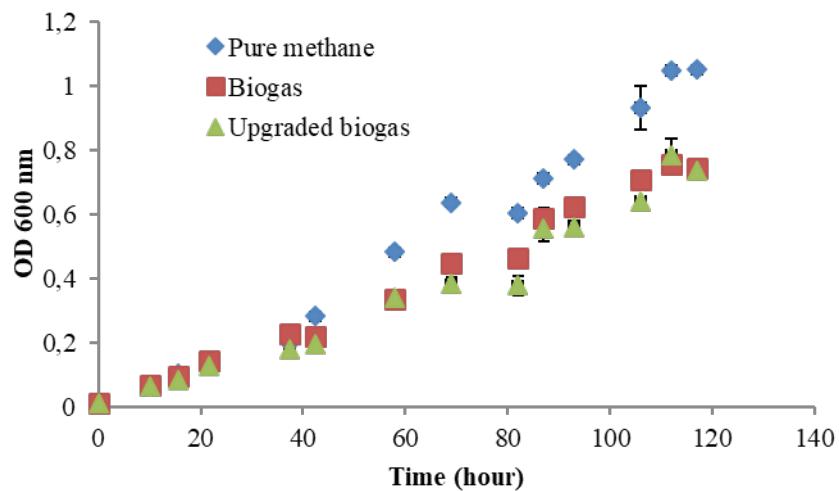
Electrochemical process

Yield and amino acid profile of SCP



$$Y_{CH_4, \text{Centr.}} = 1.34 \text{ g/g CH}_4$$

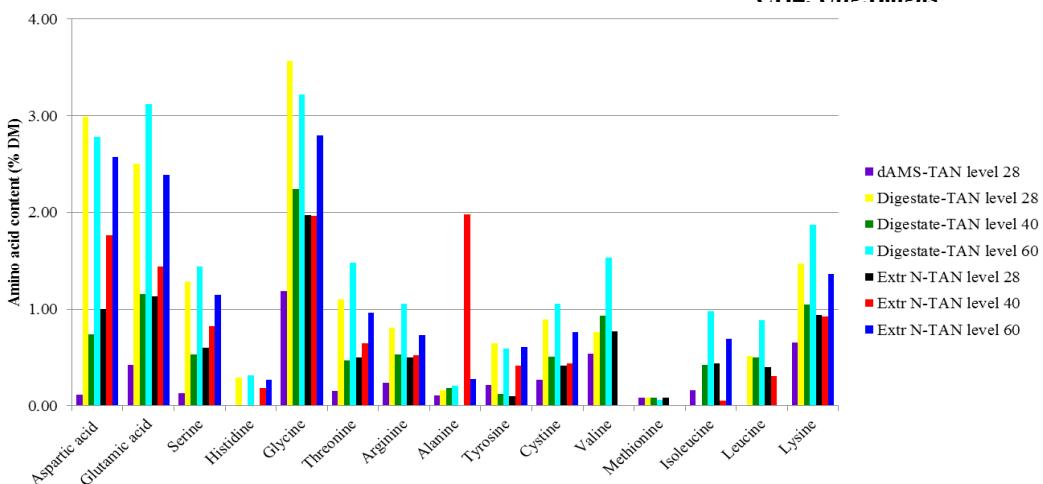
$$Y_{CH_4, \text{Elec.}} = 1.29 \text{ g/g CH}_4$$



$$Y_{CH_4, \text{pure CH}_4} = 1.14 \text{ g/g CH}_4$$

$$Y_{CH_4, \text{Biogas}} = 1.36 \text{ g/g CH}_4$$

$$Y_{CH_4, \text{Upg. Biogas}} = 1.5 \text{ g/g CH}_4$$



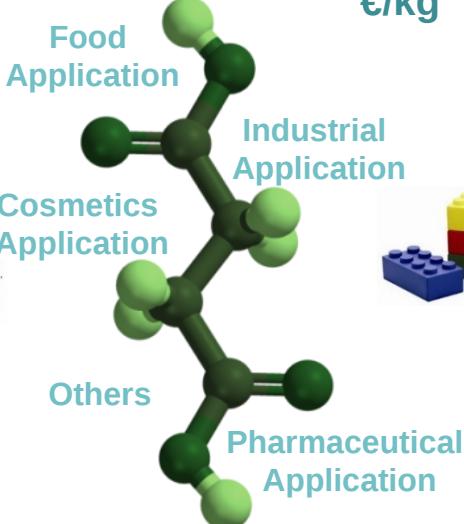
2) BioSuccinic Acid





Spot price for SA
ranges from 2.8 to 8.5

€/kg



1,4-butanediol

Succindiamide

1,4-Diaminobutane

Succinonitrile

Dibasic ester

N-Methyl-2-pyrrolidone

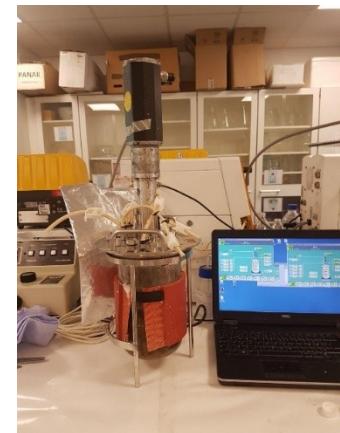
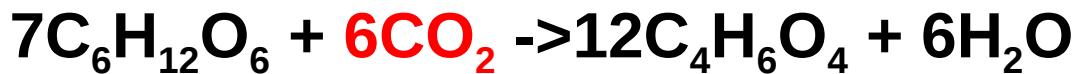
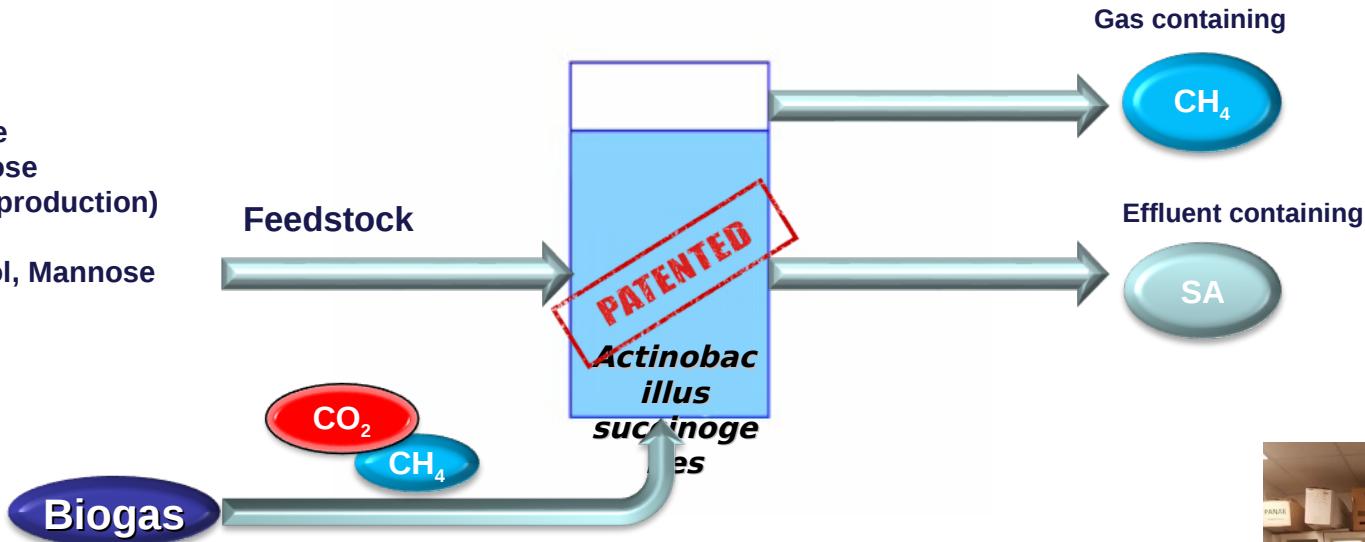
γ -Butyrolactone

2-Pyrrolidone

BioSuccinic Acid - The Technology

Simultaneous biomethane and biosuccinic acid production

Arabinose
Fructose, Fucose
Galactose, Glucose
Glycerol (Diesel production)
Lactose
Maltose, Mannitol, Mannose
Sorbitol
Sucrose (NS)
Xylose
Glycerol



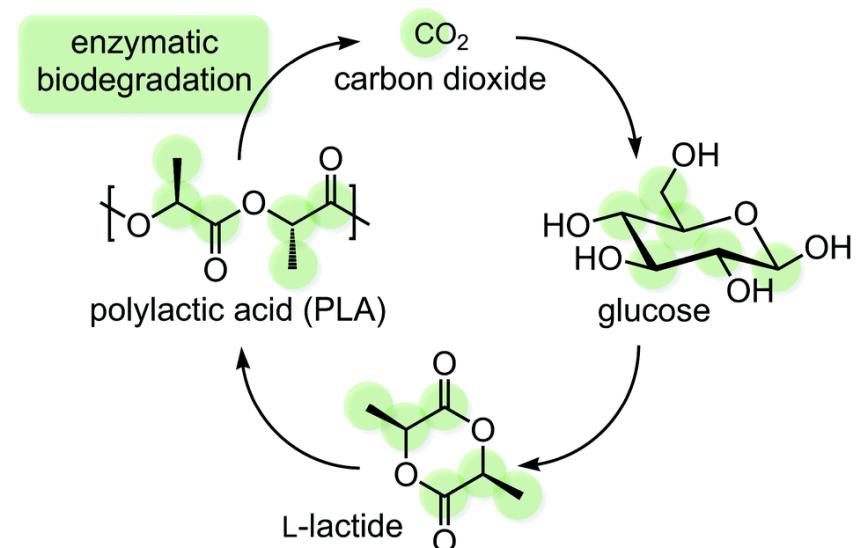
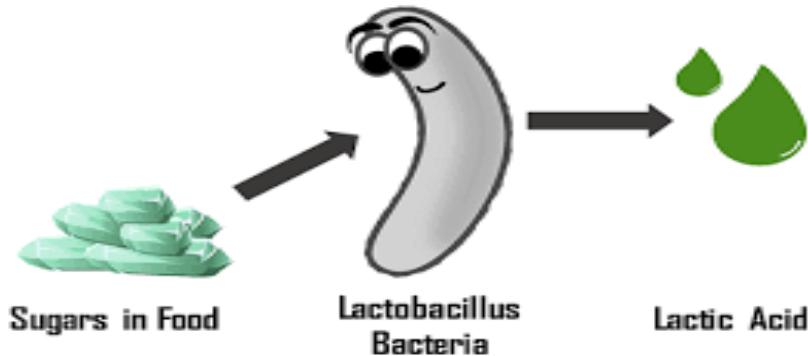
3) Lactic Acid



Lactic acid – From BioPup

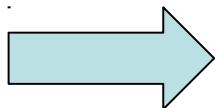
Lactic Acid Fermentation

Lactobacillus delbrueckii DSM 20074 – Homofermenter; Optical purity 100% D-lactate; Industrial LA microbe (50 °C); Good for **low pH, high ethanol**

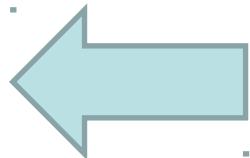


Lactic acid – From BioPulp

- Addition of *Lactobacillus delbrueckii* DSM 20074
- Pasteurisation/sterilisation
- pH adjustment
- Enzymatic pretreatment of BioPulp
- Lactic Acid Extraction

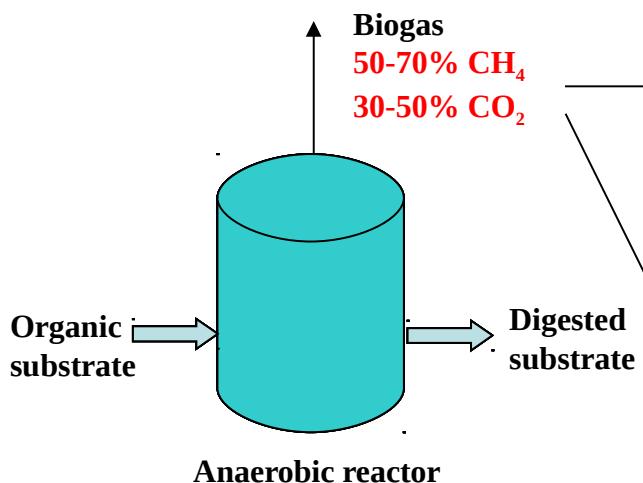


- **Lactic acid yield: with pH adjustment without LD (0.66 lactate g/g sugars)**
- **Adjusting the pH of the raw biopulp can improve the production of lactic acid by 21%**



4) Biomethane

Biogas production and utilisation



Electricity

Heat



$\text{CH}_4 > 95\%$

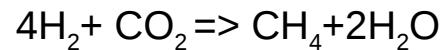
Vehicle fuels

Natural gas

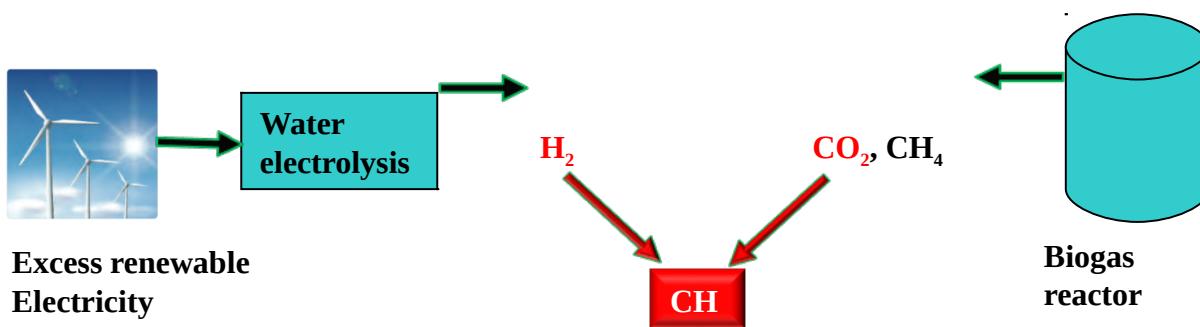


Biogas upgrading with H₂

- CO₂ together with H₂ could be used by **hydrogenotrophic methanogens** for methane production.



- H₂ could be obtained by electrolysis of water using the **surplus electricity** from eg. wind mills, or photovoltaics.



Biomethane



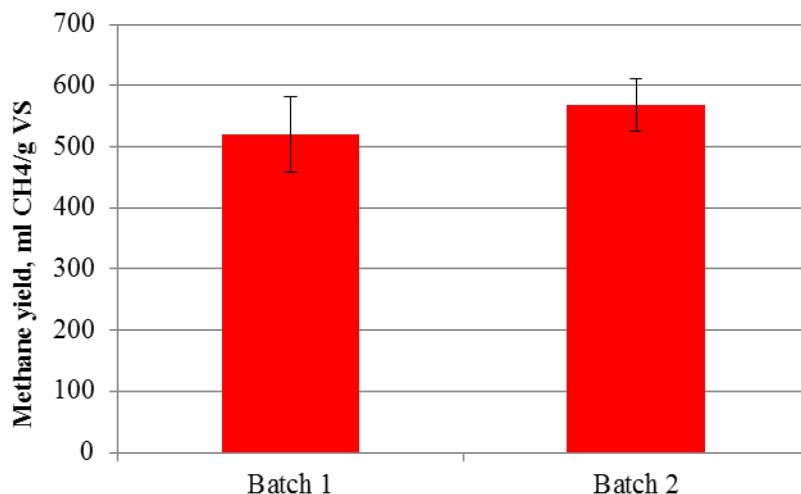
Biopulp



Biochemical methane potential



Specific methane yield =
544 ml CH₄/g VS



At confidence intervals of 95 and 99% no significant difference was observed among two batches in terms of specific methane yield

Assessemment - Scenarios

Scenario 1 - Biogas production

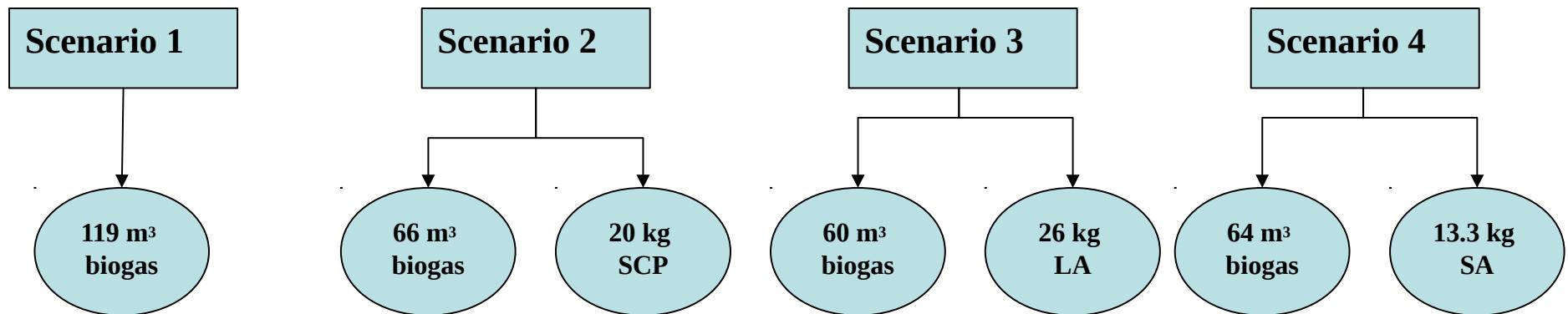
Scenario 2 - SCP production + biogas production

Scenario 3 - Lactic acid production + Biogas production

Scenario 4 - Succinic acid production + Biogas production



1 tonne Biopulp



Acknowledgements

- ✓ To all the excellent co-workers, students, collaborators that have contributed to my research

