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# Anaerobic digestion of *Jatropha curcas* oil cake

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# Biodiesel from *Jatropha curcas*



- Oil seeds producing shrub belonging to *Euphabioaceae* family.
- Seed oil content 30-40% (by weight).
- Seed yield 1-6 ton/ha.

# What to do with oil cake?



- Oil cake is toxic due to the presence of phorbol esters.
- It also contains antinutrients: saponins, phytic acid, trypsin inhibitors.



# Anaerobic digestion

## Benefits:

- Detoxification
- Recovery of the energy
- Recovery of nutrients: ammonium and phosphates
- Reduction of uncontrolled green house gases release

# Why should we recover nitrogen?

## Haber process:

- $\text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3$  ( $\Delta H = -92 \text{ kJ/mol}$ )
- $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3 \text{H}_2$  ( $\Delta H = 206 \text{ kJ/mol}$ )
- $\text{CO} + 1/2 \text{O}_2 \rightarrow \text{CO}_2$  ( $\Delta H = -283 \text{ kJ/mol}$ )
- To produce 1 ton of ammonia about 1000 m<sup>3</sup> of methane is required.

# How much can we get?

Composition of *J. curcas* oil cake:

- Volatile solids - 87.4%
- Protein - 19.9%
- Phytate - 10.5%

Maximal theoretical gain:

Biogas - 616 m<sup>3</sup>·t<sup>-1</sup>

Ammonium nitrogen - 31.8 kg·t<sup>-1</sup>

Phosphate - 89.2 kg·t<sup>-1</sup>

# Obstacle 1: Low biogas yield



*Brasica napus*  
TBY: 711 m<sup>3</sup>·t<sup>-1</sup>  
BY: 507 m<sup>3</sup>·t<sup>-1</sup>  
Efficiency: 71.3%

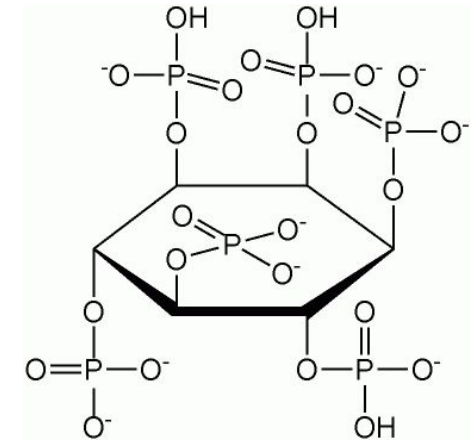
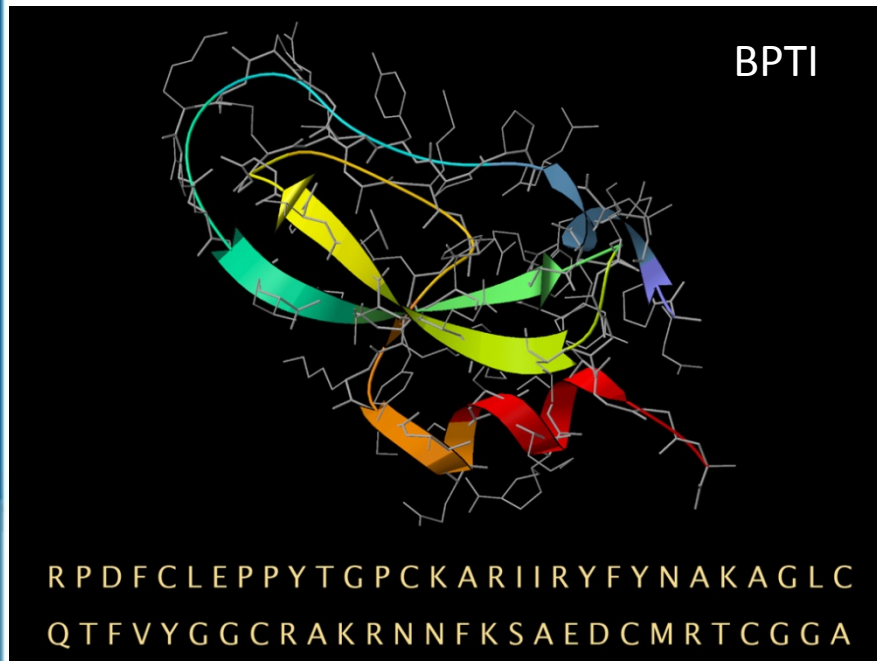


*Linum usitatissimum*  
TBY: 792 m<sup>3</sup>·t<sup>-1</sup>  
BY: 545 m<sup>3</sup>·t<sup>-1</sup>  
Efficiency: 78.8%



*Jatropha curcas*  
TBY: 616 m<sup>3</sup>·t<sup>-1</sup>  
BY: 281 m<sup>3</sup>·t<sup>-1</sup>  
**Efficiency: 45.6%**

# Possible causes



- Protease inhibitors may reduce protein digestability.
- Phytate may reduce microorganisms activity by helating metal ions.

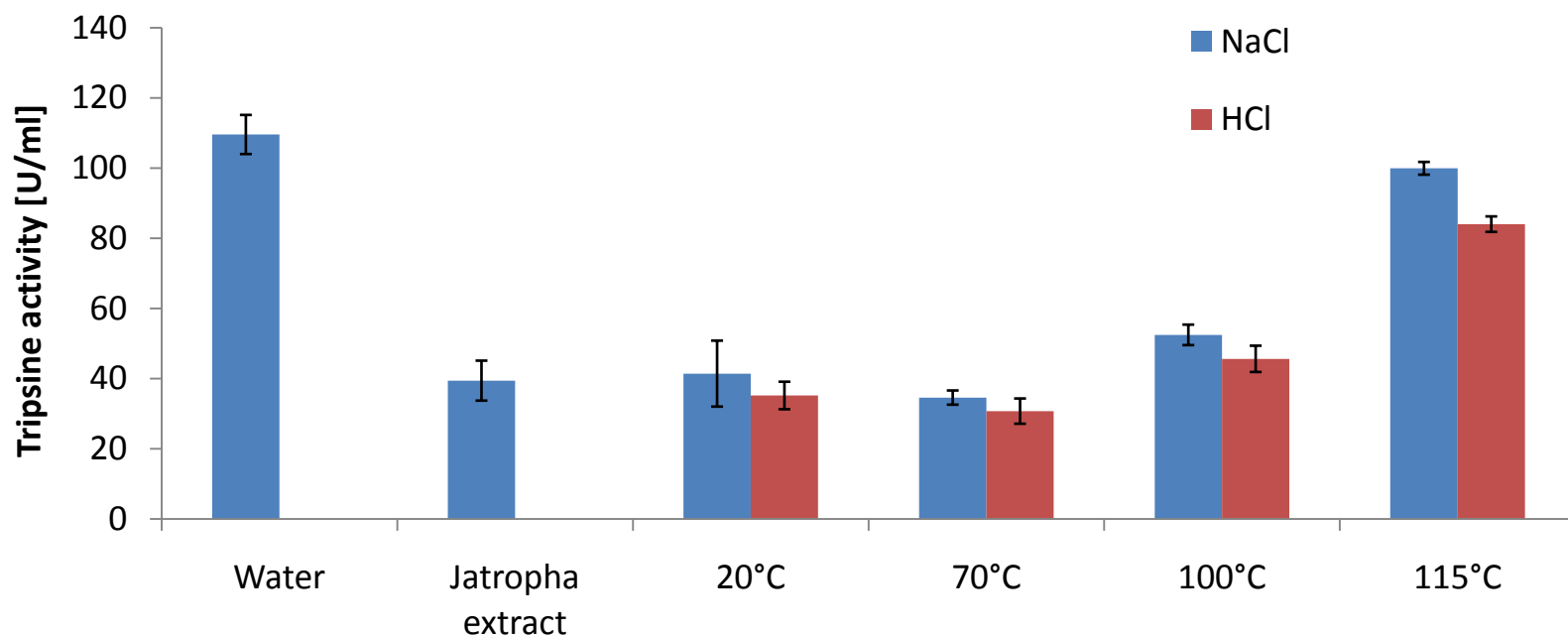


# Solution: pretreatment



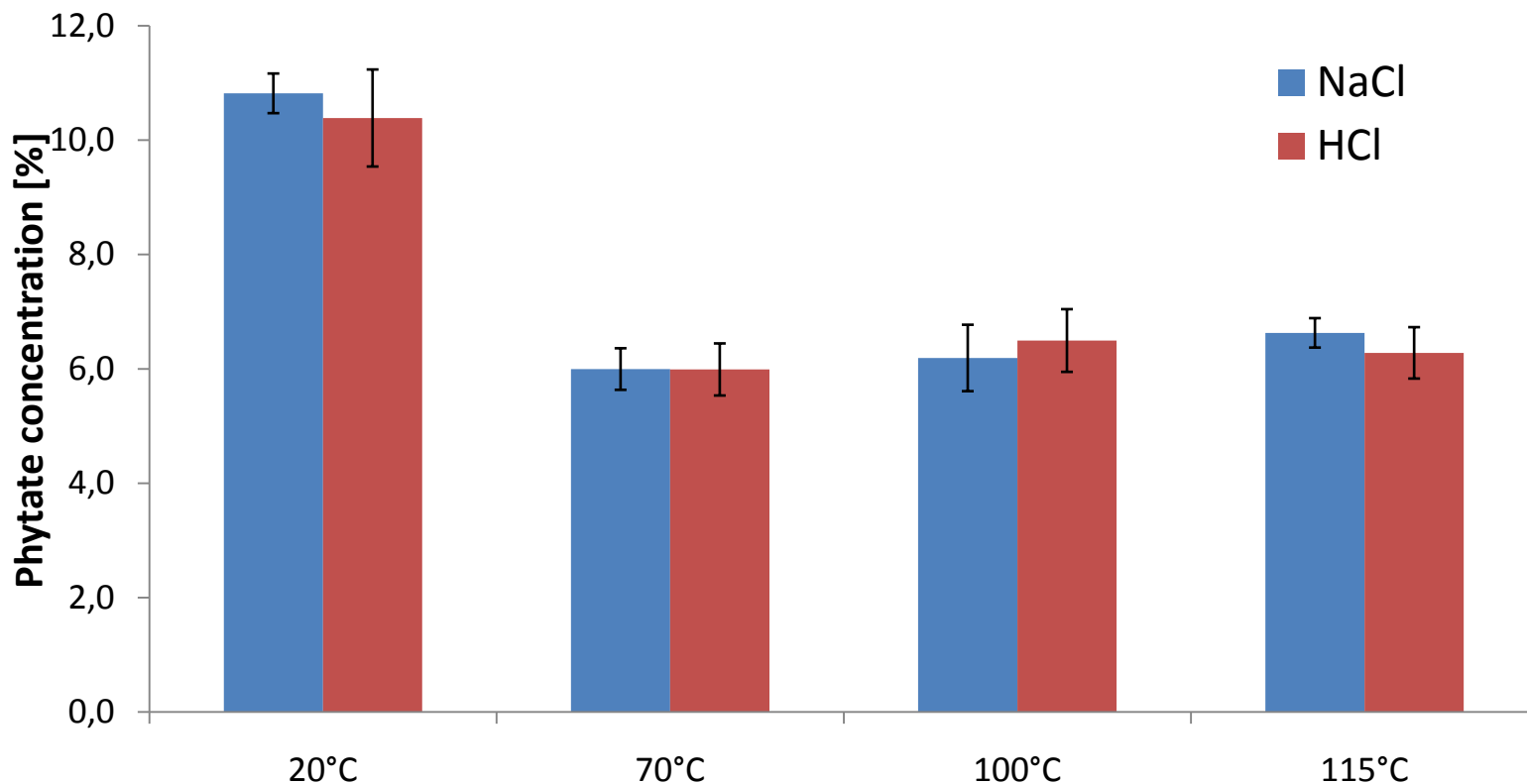
- Oilcake samples were incubated at different temperatures with NaCl solution or hydrochloric acid solution.

# Pretreatment result



- The activity of trypsin inhibitor was reduced after incubation at 115 °C.

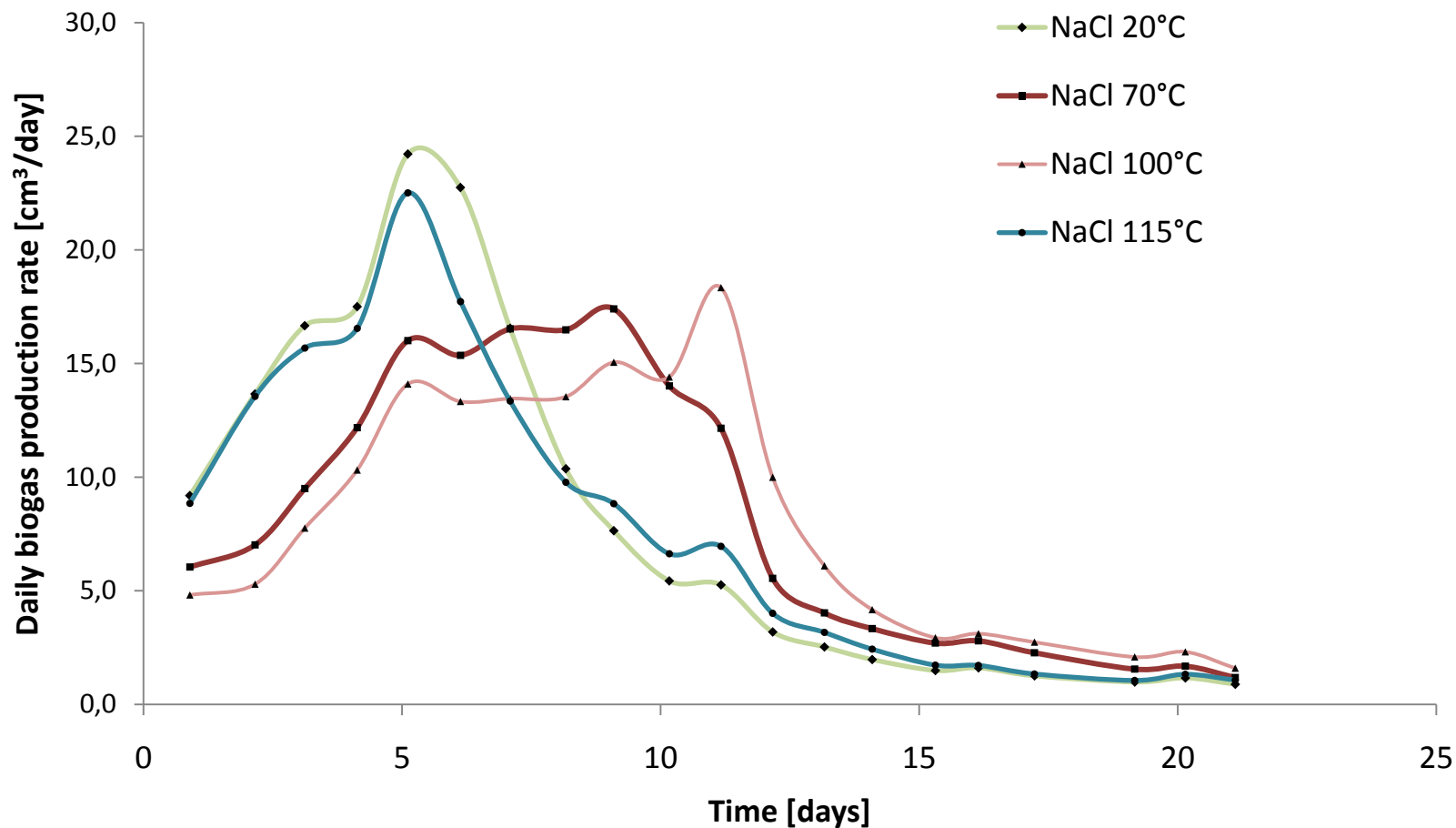
# Pretreatment result



- Concentration of phytate was also reduced even after incubation at 70°C.

# Production rate

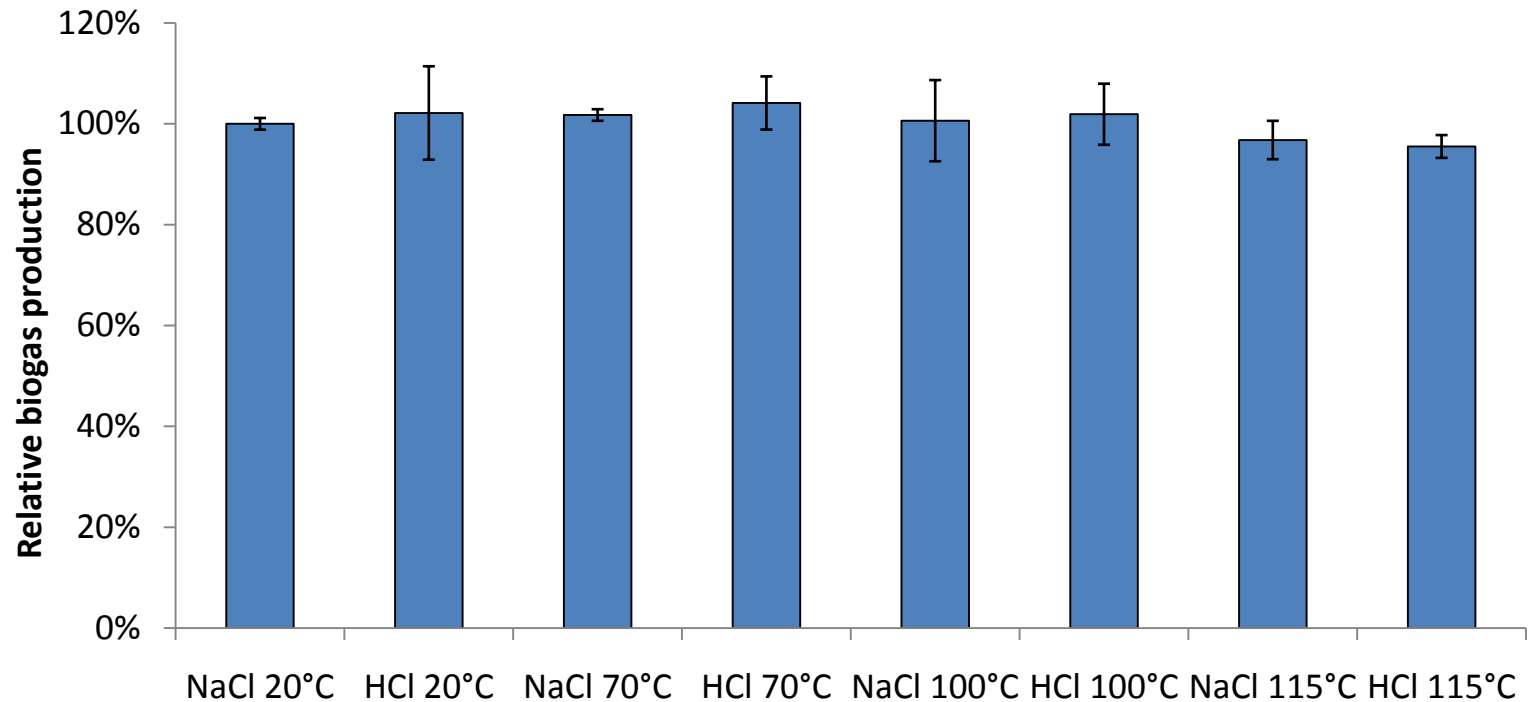
A)



Digestion rate for samples with salt addition incubated at 20 °C and 115 °C was similar, for other samples it was lower.

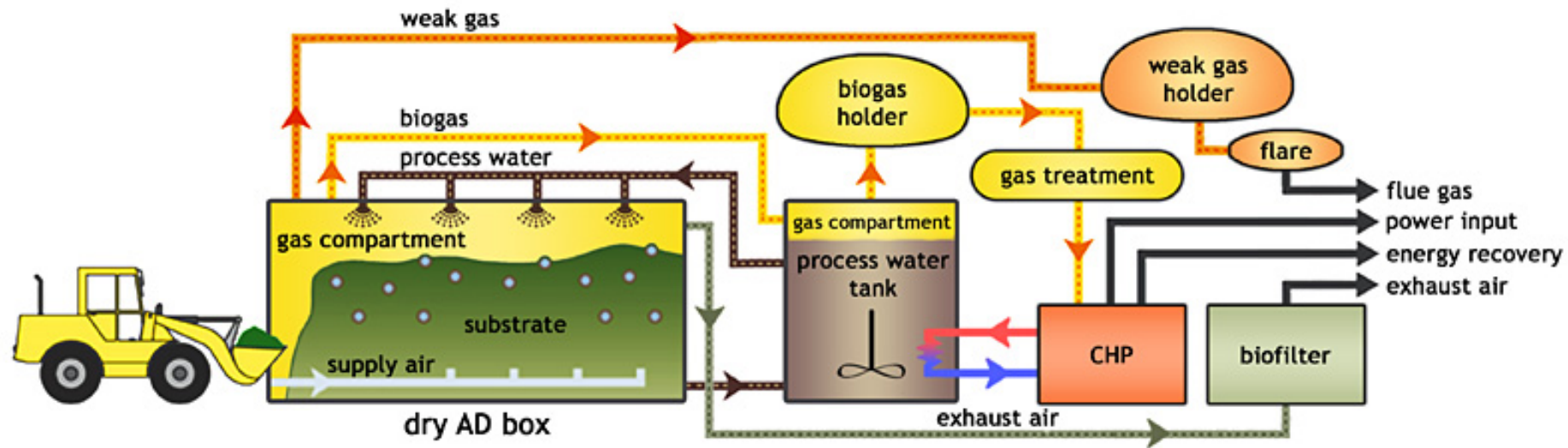


# Biogas production efficiency



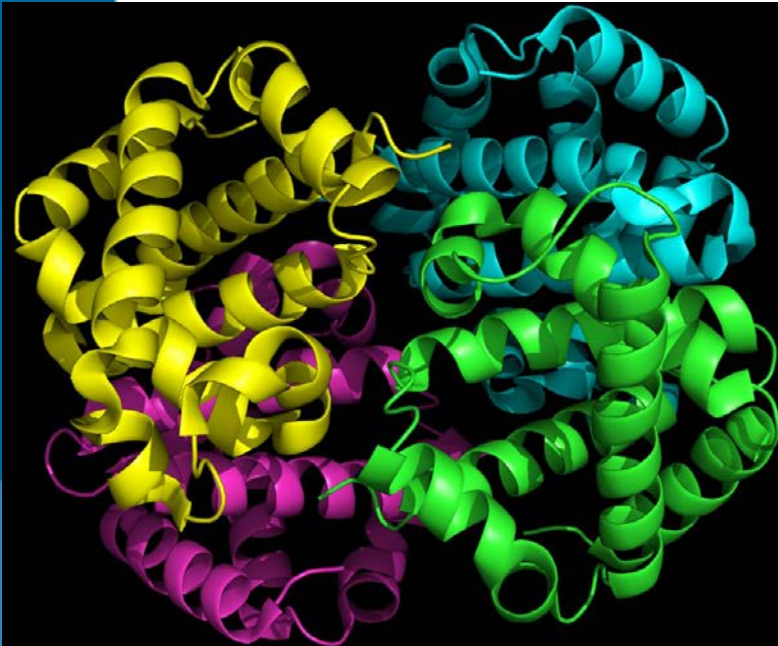
- Total biogas production level was not affected by pre-treatment.

# Alternative solution: percolation system

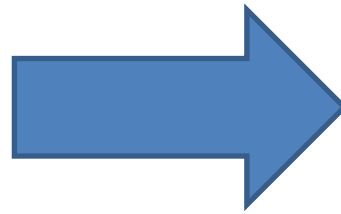


- Hydrolysis step is performed in micro aerobic conditions allowing digestion of lignin and cellulose.
- Water demand is reduced.

## Obstacle 2: Nitrogen accumulation



Proteins – 19% of *J. curcas*  
oilcake



Up to 32 kg·t<sup>-1</sup>  
of oilcake

- Digestion of proteins produces ammonia
- At high concentration ammonia is toxic to microorganisms

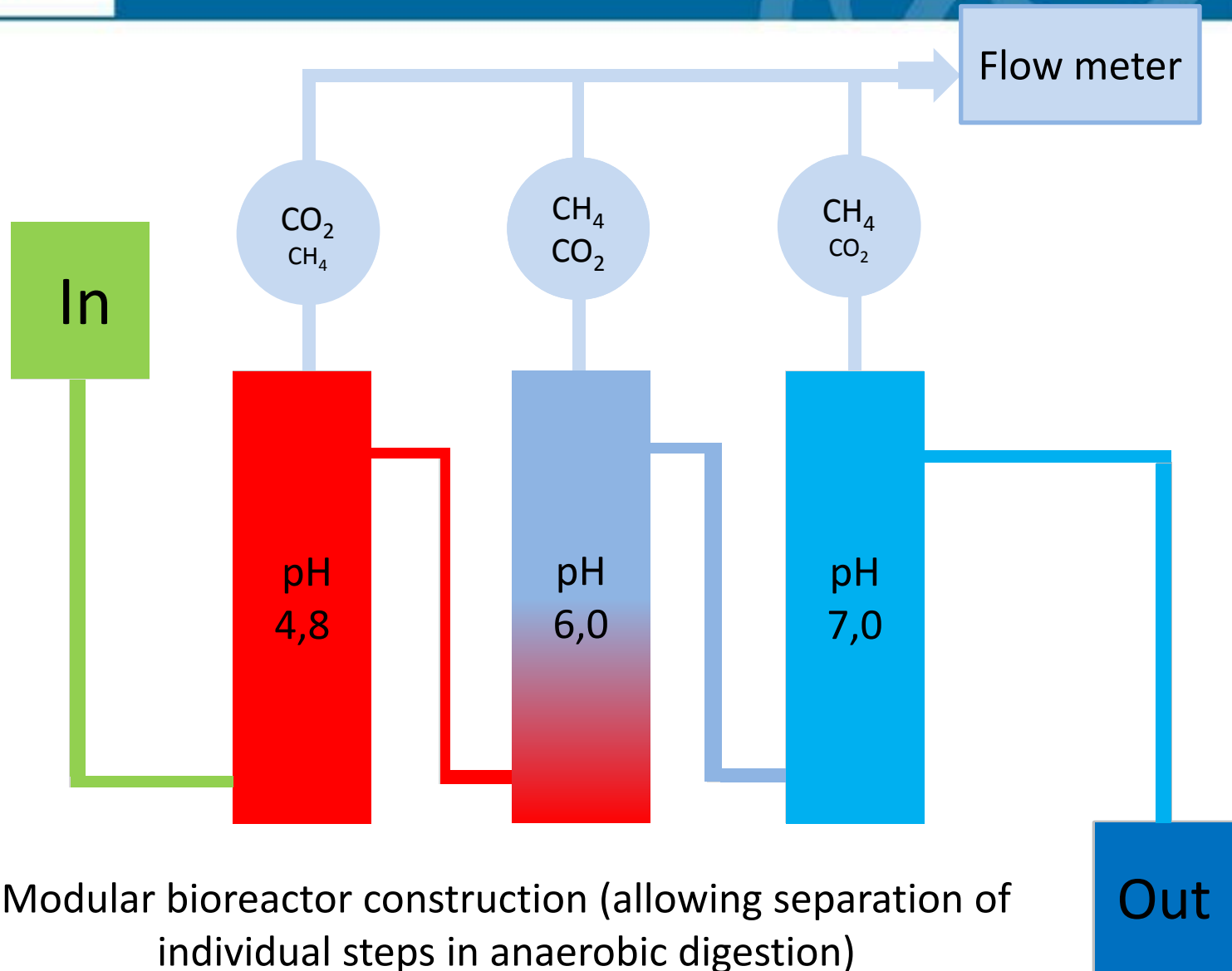
# Solution: struvite formation



- Ammonium ions may be removed from the solution by the precipitation with phosphate and magnesium.
- Nitrogen removal efficiency reached 53%.



# Other possible improvements





Methanogens



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About - Chart

Home - Class - Order - Family - Genus

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Search...

Search

Advanced

Filter methanogens

Taxonomy



Temperature [°C]



Alcalinity



Salinity [mol\*dm<sup>-3</sup>  
NaCl]



Substrate



Shape



Advanced search



All methanogens

150 methanogens



*Methanococcoides vulcani*

**Class:** Methanomicrobia

**Order:** Methanosarcinales

**Family:** Methanosarcinaceae

**Shape:** Irregular cocci

**Temp. :**

**Temp. opt. min. - max.:** 30°C - 30°C

**pH :**

**pH opt. min. - max.:** 7 - 7



*Methanospirillum stamsii*

**Class:** Methanomicrobia

**Order:** Methanomicrobiales

**Family:** Methanospirillaceae

**Shape:** Sheathed spiral

**Temp. min. - max.:** 5°C - 37°C

**Temp. opt. min. - max.:** 20°C - 30°C

**pH min. - max.:** 6 - 10

**pH opt. min. - max.:** 7 - 7.5



*Methanosarcina soligelidi*

**Class:** Methanomicrobia

**Order:** Methanosarcinales

**Family:** Methanosarcinaceae

**Shape:** Irregular cocci

**Temp. max.:** 54°C

**Temp. opt. min. - max.:** 28°C - 28°C

**pH min. - max.:** 4.8 - 9.9

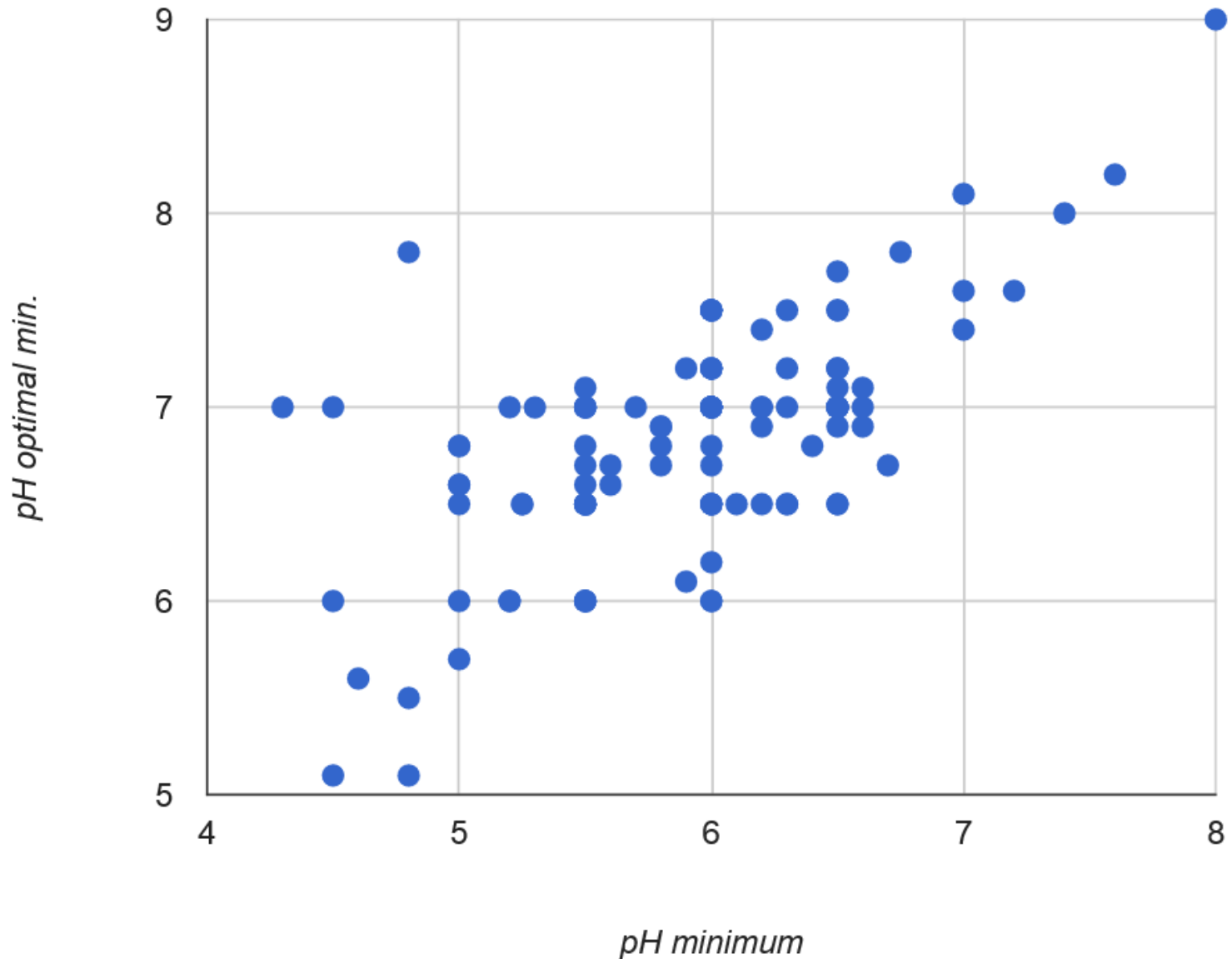
**pH opt. min. - max.:** 7.8 - 7.8



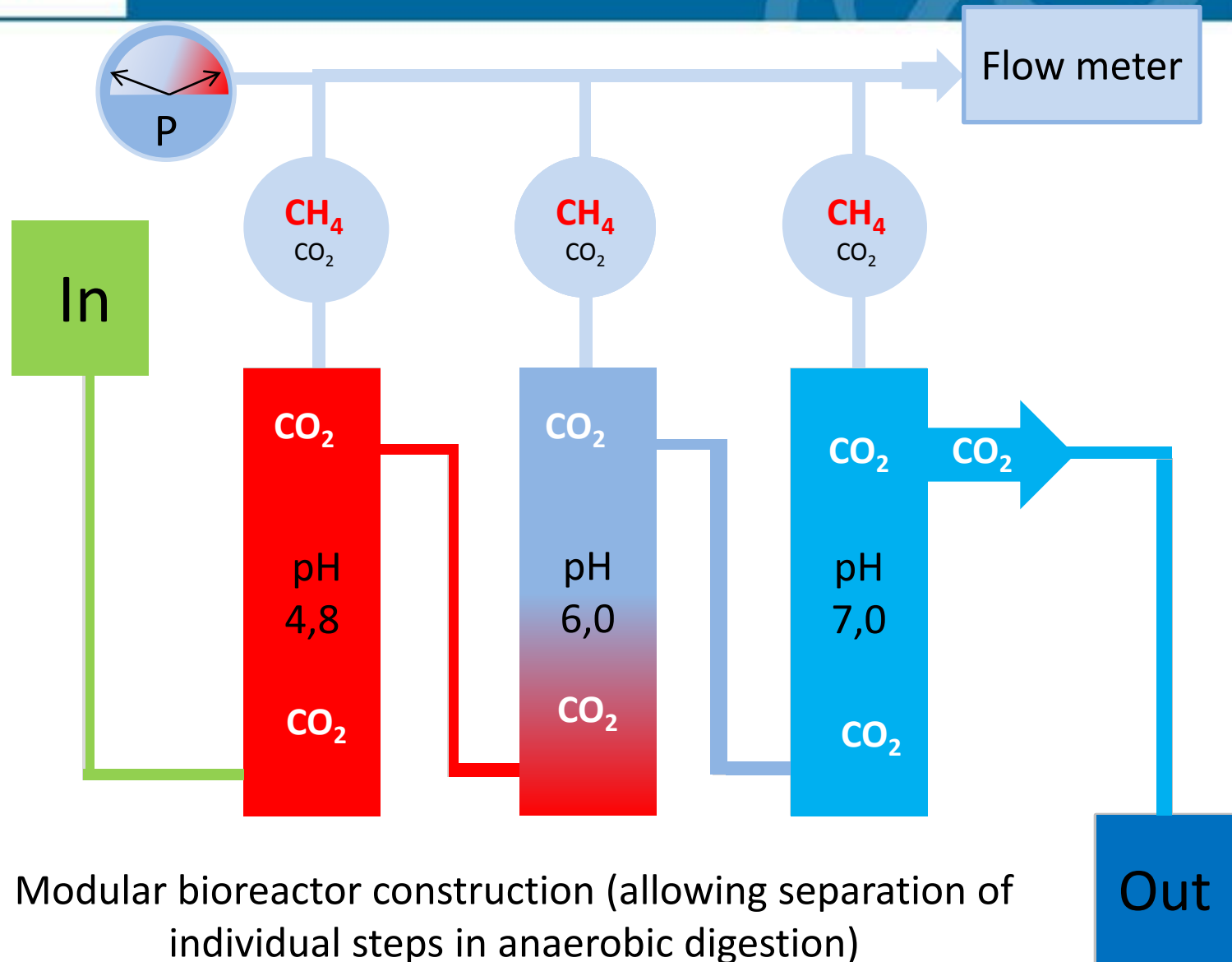
*Methanohalophilus levihalophilus*

# Metanogens growth in pH

pH minimum and pH optimal min. comparison

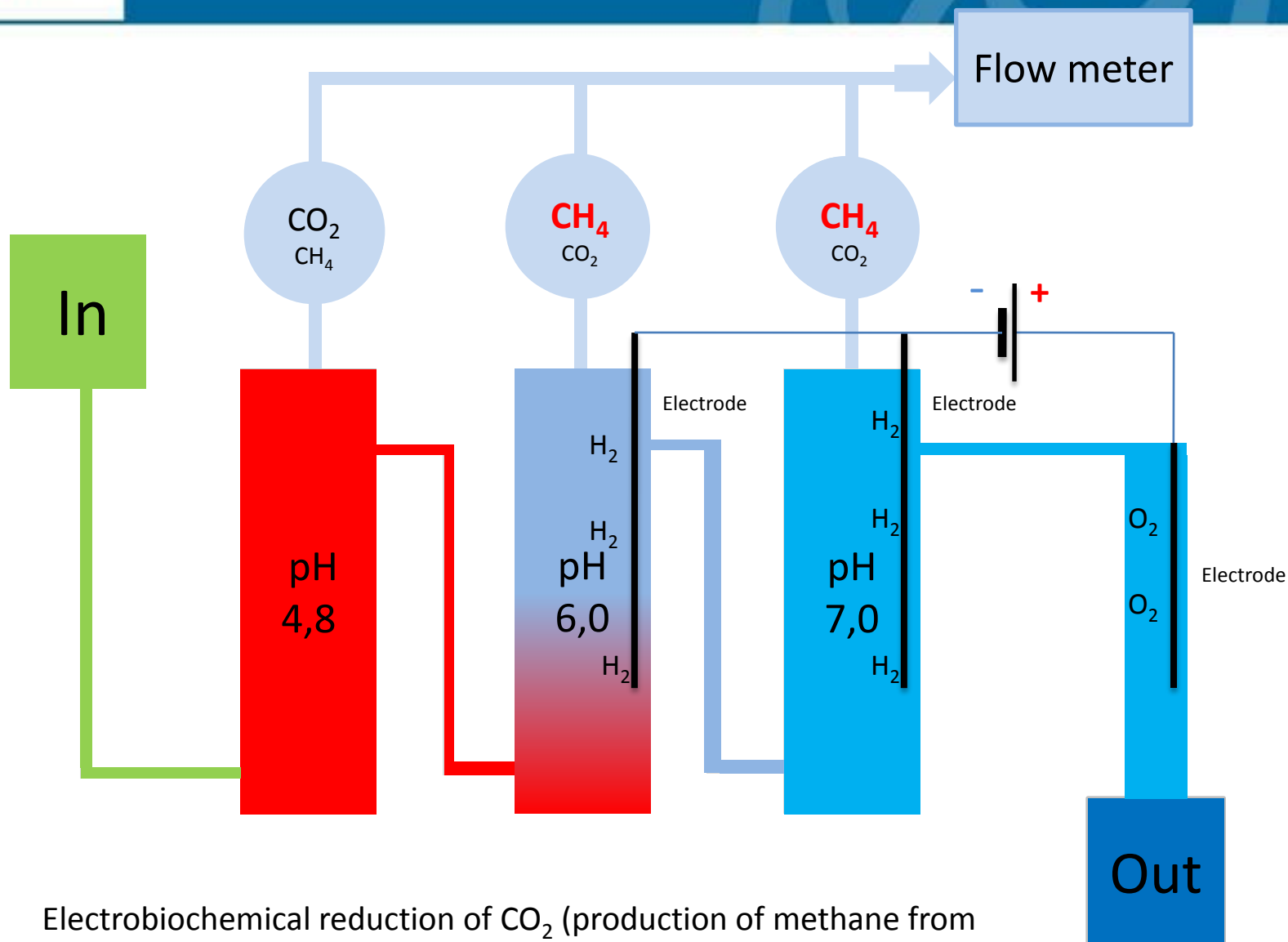


# Other possible improvements





# Other possible improvements



Electrochemical reduction of CO<sub>2</sub> (production of methane from electrical current)

# And how does it look like in reality?



# Conclusions

- Pretreatment of *J. curcas* oil cake does not improve biogas yield
- Continuous fermentation of *J. curcas* oil cake may result in process collapse due to ammonia formation
- Excessive nitrogen may be removed by struvite precipitation.
- Additional benefits such as reduction of CO<sub>2</sub> concentration may be achieved in modular bioreactor





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attention.



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