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.

Figure sources: http://cambia.pe/la-planta-jatropha-curcas-una-solucion-natural-para-mitigar-el-cambio-climatico/
What to do with oil cake?

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

Figure sources: http://hilo.hawaii.edu/sustainability/PlantOil.php
Anaerobic digestion

Benefits:

• Detoxification

• Recovery of the energy

• Recovery of nutrients: ammonium and phosphates

• Reduction of uncontrolled green house gases release

Figure sources: http://sites.duke.edu/environ398_10_f2010_ct95/?page_id=46
Why should we recover nitrogen?

Haber process:

- \( \text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3 \) \( \Delta H = -92 \text{ kJ/mol} \)
- \( \text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3 \text{H}_2 \) \( \Delta H = 206 \text{ kJ/mol} \)
- \( \text{CO} + \frac{1}{2} \text{O}_2 \rightarrow \text{CO}_2 \) \( \Delta H = -283 \text{ kJ/mol} \)

- To produce 1 ton of ammonia about 1000 m³ 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 m³·t⁻¹
- Ammonium nitrogen - 31.8 kg·t⁻¹
- Phosphate - 89.2 kg·t⁻¹
Obstacle 1: Low biogas yield

*Brasica napus*
- TBY: 711 m$^3$.t$^{-1}$
- BY: 507 m$^3$.t$^{-1}$
- Efficiency: 71.3%

*Linum usitatissimum*
- TBY: 792 m$^3$.t$^{-1}$
- BY: 545 m$^3$.t$^{-1}$
- Efficiency: 78.8%

*Jatropha curcas*
- TBY: 616 m$^3$.t$^{-1}$
- BY: 281 m$^3$.t$^{-1}$
- Efficiency: 45.6%

Possible causes

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

Figure sources: https://pl.wikipedia.org/
Solution: pretreatment

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

Figure sources: hdimagegallery.net,
• The activity of trypsin inhibitor was reduced after incubation at 115 °C.
Concentration of phytate was also reduced even after incubation at 70°C.
Production rate

Digestion rate for samples with salt addition incubated at 20 °C and 115 °C was similar, for other samples it was lower.
• Total biogas production level was not affected by preptreatment.
Alternative solution: percolation system

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

Figure sources: http://www.herhof.com/en/products/biogas-system.html
Obstacle 2: Nitrogen accumulation

Proteins – 19% of *J. curcas* oilcake

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

Figure sources: [www.caslab.com](http://www.caslab.com), [http://www.helsinki.fi/~pjojala/Hemoglobin.htm](http://www.helsinki.fi/~pjojala/Hemoglobin.htm)
Solution: struvite formation

(NH₄)MgPO₄·6(H₂O)

• Ammonium ions may be removed from the solution by the precipitation with phosphate and magnesium.

• Nitrogen removal efficiency reached 53%.

Figure sources:https://pl.wikipedia.org/wiki/Struwit
Other possible improvements

Modular bioreactor construction (allowing separation of individual steps in anaerobic digestion)
Metanogens growth in pH

pH minimum and pH optimal min. comparison

pH optimal min.
pH minimum
Other possible improvements

Modular bioreactor construction (allowing separation of individual steps in anaerobic digestion)
Electrobiochemical reduction of CO₂ (production of methane from electrical current)

Other possible improvements
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$_2$ concentration may be achieved in modular bioreactor
Thank you for your attention.