Environmental evaluation of innovative biorefinery process

K. Czerwinska¹, S. Del Pero², L. Lombardi³, A. Polettini⁴, R. Pomi⁴, A. Rossi⁴, S. Shivali³, M. Sliz¹, M. Wilk¹, T. Zonfa⁴

¹AGH University of Science and Technology, Kraków, Poland
²University of Florence, Florence, Italy
³Niccolò Cusano University, Rome, Italy
⁴Department of Civil and Environmental Engineering, University of Rome “La Sapienza”, Rome, Italy
Summary

- BBCircle project

Materials and method
- Life Cycle Assessment
- Goal and scope definition (G&S)
- Life Cycle Inventory (LCI)

Results and discussion - preliminary
- Life Cycle Impact Assessment (LCIA)

Conclusions
**BBCircle project**

The BBCircle project, funded by the Lazio Region (IT), is aimed at integrating different processes to produce biomaterials, biofuels, capturing CO$_2$ and promote circularity, in reference to the suitable and available substrates in the regional territory. (2021-2023)

**Link**

BBCircle – Biomaterials, Biofuels, CO2 sequestration and Circularity. A study about the possibility to implement Biorefineries in the Lazio Regione


http://www.dicea.uniroma1.it/node/1220
**BBCircle project – Biorefinery configuration**

“... is aimed at integrating different processes to produce biomaterials, biofuels, capturing \( \text{CO}_2 \) and promote circularity, in reference to the suitable and available substrates in the regional territory. The biorefinery approach will be implemented...”

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**Research pathway**

- **Laboratory tests** → **Preliminary design of process layout** → **LCA**
Dairy industry

- Dairy products in EU-28 area: 160 millions in 2020 (FAO)
- 9-10 L of CW per kg of cheese produced
- CW organic load: 50-100 g COD/L

Environmental issue
- Eutrophication in waterbodies
- Toxicity to aquatic animals
- Decrease in crop yield

Huge opportunity to recover:
- Bioenergy
- Bioproducts

Management strategies

Past
- Fertiliser
- Animal feed
- Disposed

Present & Future

Extraction/separation processes
- Proteins
- VFA

Anaerobic digestion
- CH₄-rich gas

Fermentative processes
- H₂-rich gas
- PHA
- EE

BBCircle project – Cheese whey as substrate
Materials and method – Life Cycle Assessment

Goal & scope definition:
- Evaluation of the sub-processes contribution
- Comparison of two alternative processes

Environmental evaluation of innovative biorefinery process
Goal & scope definition

Functional Unit: 1 t CW

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Avoided H₂

Cheese Whey

Dark Fermentation

H₂

CO₂ REMOVAL

CO₂/H₂

Fermentate

Hydrochar

HTC

Lignite substitution in power plants

Avoided H₂

Cheese Whey

Enhanced Bio-Electrochemical Dark Fermentation

H₂

CO₂ REMOVAL

CO₂/H₂

Fermentate

Hydrochar

HTC

Lignite substitution in power plants

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Goal & scope definition

Integrated Bio-Electrochemical System (IBES)

- Biogas yield: 3.6 kg/t CW
- Biogas composition (%vol.): 60 H₂-40 CO₂
- H₂ yield: 2.69 NL/kg CW
- Fermentate: 1.1 t/t CW
- EE prodotta: 0.08 kWh/t CW

Stand-alone dark fermentation

- Biogas yield: 13.5 kg/t CW
- Biogas composition (%vol.): 50 H₂-50 CO₂
- H₂ yield: 6.57 NL/kg CW
- Fermentate: 1.3 t/t CW

- Additional electrochemical generation of H₂
- EE generation
- No need to add buffering agent (NaOH) continuously
- Consumption and replacement of zinc electrode
- Depletion of anode solution (ZnSO₄) and need to treat and replacement

- Higher biogas yield
- Higher H₂ yield
- Need to add buffering agent (NaOH) continuously

Substitution interval: once a day – once a year

Adapted from: De Gioannis et al., 2021

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Results and discussion – Impact Assessment (CC)

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Results and discussion – Impact Assessment (CC)

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<tr>
<th>DARK FERMENTATION</th>
<th>kg CO2 eq</th>
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<tr>
<td>EE</td>
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<td>NaOH</td>
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<td>Water</td>
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<th>HTC</th>
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Environmental evaluation of innovative biorefinery process
Results and discussion – Impact Assessment (CC)

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<th>IBES</th>
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<td>Anodic solution to WWTP</td>
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<td>ZnSO4</td>
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<td>Water</td>
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Conclusions

- Introducing the IBES process in place of DF reduces a lot the impact of NaOH use.
- But uncertainty remains on the degradation of the ZnSO₄ solution.
- To be competitive the ZnSO₄ solution should last at least 12 days.
- Environmental credits are not able to balance the consumptions impacts of biorefinery system.
- The main environmental credits come from hydrochar use.
- Biorefinery results are promising: further aspects need to be investigated and further efforts must be invested in the experimental verification → LCA can support this process.
- Other processes and other substrates are under investigation.

Life-cycle thinking

SUSTAINABLE CIRCULAR ECONOMY
Thank You!

Lidia Lombardi
Niccolò Cusano University
Rome, Italy

lidia.lombardi@unicusano.it
10th International Conference on Sustainable Solid Waste Management

Results and discussion – Impact Assessment (CC)

LCIA method: Environmental Footprint

Climate change (kg CO2 eq/t CW)

Environmental life cycle assessment of polyhydroxyalkanoates production from cheese whey

Fabiano Asmus,1 Giorgia De Giusti,2,3 Giovanni Francini,1 Lidia Lombardi,1 Aldo Muntoni1, Alessandra Polentini1, Raffaella Pomi1, Andrea Poni1, Daniela Spiga1

1 Department of Civil and Environmental Engineering and Architecture, University of Cagliari, Via Roma 2, 09123 Cagliari, Italy
2 CNR – CIR, Institute of Geological, Archeological and Environmental Geosciences, Cagliari National Research Council, Piazzale Europa, 09124 Cagliari, Italy
3 Department of Civil and Environmental Engineering, University of Florence, Via Santa Marta 3, 50139 Florence, Italy
4 Faculty of Engineering, University of Rome “La Sapienza”, Via Eudossiana 18, 00184 Rome, Italy
5 Department of Civil and Environmental Engineering, University of Rome “La Sapienza”, Via Eudossiana 18, 00184 Rome, Italy

Biorefinery scenario - DF

Biorefinery scenario - IBES

AD scenario

-3.57

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