Microalgae biorefinery: an integrated approach towards sustainable biofuels production

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Accounting that the global demand for sustainable energy increases, microalgae biorefineries attract the research interest towards biofuels and high-added value chemicals co-production. The biomass-based biorefinery concept is analogous to a petroleum refinery, which employes integrated biological and thermochemical conversion processes to produce various biofuels and bioproducts. To this end, the life cycle assessment (LCA) of microalgae biorefinery enable the quantification of its environmental impacts assessment, towards the identification of sustainable biofuels and biochemicals production routes (Sun *et al* 2019; Ubando *et al* 2023). In particular, LCA is an internationally standardized methodology that quantifies the environmental potential impacts associated with a product by collecting the inputs and outputs of the examined production process and evaluating the associated impacts with them by interpreting the results obtained in the inventory analysis based on the impact assessment categories.

In this context, the Sunfeeding project aspires to contribute to microalgae cultivation under a biorefinery concept providing primarily food supplement and animal feed, whereas high-value co-products and renewable fuels are co-produced, as well. More specifically, the Sunfeeding project valorizes microalgae biomass towards primary products (food supplement, animal feed) and secondary products (renewable fuels) symbiosis single platform with a scope to reduce global dependency on the fossil fuels.

Figure 1 depicts the system boundaries of the examined production process, covering all stages from microalgae cultivation to renewable fuels production through catalytic hydrotreatment.

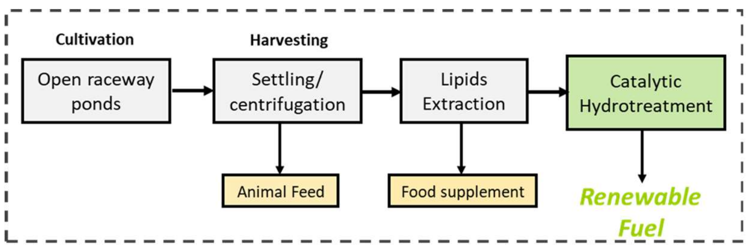

Figure 1. System boundaries of the examined microalgae based biorefinery

Open raceway ponds were chosen to grow microalgae *Chlorella Sorokiniana* in this study, while the biomass after its harvest was processed for animal feed. The extracted lipids of the biomass were processed for yogurt food supplement, and were also converted to renewable fuels via catalytic hydrotreatment. Particularly, the present study focusses on the renewable fuels production via catalytic hydrotreatment. An attempt to compare the examined production scheme with the transesterification, a common technology to produce bio-oil from biomass, in which triglycerides react with an alcohol in the presence of a catalyst is also in progress.

Experimental and literature data, as well as databases were utilized for the LCA study. Furthermore, a process simulation model for the derived lipids upgrading via catalytic hydrotreatment using Aspen Plus V. 11 was developed. The life-cycle impacts are quantified in terms of NER and GWP. NER is defined as the ratio of energy consumed to energy produced and is used to evaluate the energetic effectiveness of each process and the overall system. GWP (Global Warming Potential) is a key link between biofuel production and environmental impacts. The accumulative greenhouse gas (GHG) emissions for microalgae-based biofuel production are generally determined by the emissions of each process including energy (i.e., electricity, natural gas, and petroleum) production and consumption, materials (i.e., chemicals) production and energy recovery (i.e., the combustion of by-products).

This study conducted an LCA of microalgae-based biorefinery from the strain of *Chlorella Sorokiniana* to obtain a better understanding of its environmental impacts for the production of a wide range of products for food supplement, animal feed and renewable fuels. Table 1 depicts the preliminary calculated accumulative GHG emissions.

Table 1. Accumulated GHG emissions

Process stage	Renewable fuel production*
Cultivation	-115
Harvesting	49
Drying	-
Lipids Extraction	45
Catalytic hydrotreatment	8
Total	-13

*The unit of GHG gas emissions of renewable fuel production is g CO_2eq/MJ renewable fuel

Based on the preliminary results, microalgae biomass constitutes a potential bioenergy feedstock towards biofuels production. Nonetheless, zerowaste biorefinery approach is at the early developmental stages but yet is promising based on environmental aspects. However, further studies are required at pilot-scale to validate the sustainability of zero-waste microalgal biorefinery schemes.

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