



A biorefinery from *Nannochloropsis* sp. microalga – Energy and CO₂ emission and economic analyses

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HIGHLIGHTS

- Oil obtained by SE has the lowest energy and CO₂ values per MJ_{prod.}
- Oil obtained by SFE proved to be more economically viable, with a cost of 365 €/kg_{oil}.
- Biorefinery 2 (biodiesel SFE + bioH₂) has the best energy/CO₂/economy compromise.
- The bioH₂ as co-product may be advantageous in terms of product yield or profit.
- High-value pigments can be produced by SFE which is a clean technology.

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ABSTRACT

Are microalgae a potential energy source for biofuel production? This paper presents the laboratory results from a *Nannochloropsis* sp. microalga biorefinery for the production of oil, high-value pigments, and biohydrogen (bioH₂). The energy consumption and CO₂ emissions involved in the whole process (microalgae cultivation, harvest, dewater, mill, extraction and leftover biomass fermentation) were evaluated. An economic evaluation was also performed. Oil was obtained by soxhlet (SE) and supercritical fluid extraction (SFE). The bioH₂ was produced by fermentation of the leftover biomass. The oil production pathway by SE shows the lowest value of energy consumption, 177–245 MJ/MJ_{prod.}, and CO₂ emissions, 13–15 kgCO₂/MJ_{prod.}. Despite consuming and emitting c.a. 20% more than the SE pathway, the oil obtained by SFE, proved to be more economically viable, with a cost of 365€/kg_{oil} produced and simultaneously extracting high-value pigments. The bioH₂ as co-product may be advantageous in terms of product yield or profit.

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1. Introduction

Microalgal biomass has the potential to provide renewable energy (e.g. biodiesel, bioethanol, biohydrogen and biogas) through the production of different energy vectors. In addition, they also have the capacity to synthesize bioactive molecules, such as carotenoids, fatty acids, antioxidants, anti-inflammatory and other valuable organic compounds, which can be used in food, feed, cosmetic, biomaterials, nanostructures and pharmaceutical industries (Marques et al., 2011). A systemic approach to the culture and refinery of microalgae is therefore essential and should integrate the production of biofuels and co-products. The biorefinery

approach consists in the production of a wide range of biofuels and chemicals from biomass and it assists in making biofuel production economically feasible (Gouveia, 2011).

Without competing with food cultures, arable land, potable water and having a higher productivity and the possibility of daily harvesting, the microalgae potential for biofuel production is huge. However, the current implementation of microalga-based systems has been economically constrained by their still poor volumetric efficiencies, which still lead to excessively high costs compared to petroleum prices. Moreover, technological drawbacks are also present, namely the maximum biomass concentration attainable in the available photobioreactors, the biomass productivity, the efficiency of harvesting and the relatively low microalga intrinsic lipid content (Amaro et al., 2011). Therefore a careful assessment of the life cycle energy balances – including actual environmental

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