Photobioreactors for microalgal growth and oil production with *Nannochloropsis salina*: From lab-scale experiments to large-scale design

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**A B S T R A C T**

This paper reports new experimental data of microalgae growth and lipid production under autotrophic conditions for the species *Nannochloropsis salina*. The effect of relevant operating variables is addressed and discussed, and some suggestions to better understand the process behavior are given with respect to lipid content maximization, carbon dioxide and nitrogen supply, and illumination conditions. The data obtained are finally desiged to the design of an environmentally and economically sustainable photobioreactor in view of achieving industrial photosynthetic biomass and natural oil production from large scale microalgae cultivation.

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1. Introduction

The interest in microalgae cultivation is currently very high because microalgal oil, among other uses, could represent an alternative to complement and eventually replace fossil fuels in the years to come.

Research concerning lipid production from microalgae was stimulated in the past three decades by the increasing shortage of crude oil. Natural oil from microalgae seems to be the only renewable biofuel with the potential to completely displace petroleum-derived transport fuels because, at least in principle, it can be employed for the production of biodiesel in an economically effective and environmentally sustainable manner (Chisti, 2007). Although this point has been recently questioned by a life cycle analysis (LCA) (Clarens et al., 2010), the unavailability of industrial plant commercial data currently hinders any adequate LCA study, and more research efforts are needed not only to show the process feasibility at the industrial scale, but also to provide further experimental and theoretical support to the implied technology.

Microalgae are a highly diverse group of unicellular photosynthetic organisms comprising eukaryotes and prokaryotic cyanobacteria, that can grow at a much faster rate than plants thanks to their simple structure (Day et al., 1999). Unlike the case of first-generation biodiesel, the extensive cultivation of microalgae does not compete for agricultural land with food crops, since they can be grown on marginal land or in aquatic systems. However, in order to become economically feasible, the cultivation of microalgae for biofuel production requires high biomass and lipid productivity per area and minimum plant investment and operating costs.

The two options for massive production of microalgae are open systems, such as raceway ponds, and closed photobioreactors. Open cultures are inexpensive but bring about important drawbacks, including lower long-term productivity due to limited exposition to light, complex carbon management and large susceptibility to contamination (Wahal and Viamajala, 2010). In the case of photobioreactors, initial capital investments are certainly more demanding, but they can provide higher overall productivity thanks to better contaminant management and improved utilization of photosynthetically active radiation, carbon dioxide and other nutrients. The design of closed systems must be carefully optimized for each individual microalgal strains, according to its specific physiological and growth characteristics. Apparently, major technical and economic challenges still prevent the selection

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