



Productivity, carbon utilization, and energy content of mass in scalable microalgae systems

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ABSTRACT

This study was designed to examine carbon utilization within scalable microalgae production systems. *Neochloris oleoabundans* was produced in replicated troughs containing BG11 nutrient formulation. Atmospheric CO₂ was supplemented with ~5% CO₂ or with NaHCO₃, and the pH of troughs receiving NaHCO₃ was adjusted with HCl or H₃PO₄. Peak biomass concentrations reached 950, 1140, or 850 mg L⁻¹ and biomass productivities of 109, 96, and 74 mg L⁻¹ day⁻¹ were achieved in the CO₂, NaHCO₃:HCl and NaHCO₃:H₃PO₄ troughs, respectively. The highest productivity is expected in a scaled-up continuous batch process of the CO₂ supplemented system, which was projected to yield 8948 L lipids ha⁻¹ yr⁻¹. Carbon utilization in the CO₂, NaHCO₃:HCl and NaHCO₃:H₃PO₄ systems was ~0.5, 15.5, and 12.9%, while the energy content of the combustible biomass was 26.7, 13.2, and 15.4 MJ kg⁻¹, respectively. Techno-economic analyses of microalgal production systems should consider efficiencies and cost-benefit of various carbon sources.

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1. Introduction

Global rates of energy consumption are not sustainable considering the increase in global population, energy consumption per capita, and our continued reliance on non-renewable energy reserves. Researchers around the world are diligently searching for abundant, cost effective, and renewable replacements for petroleum, natural gas and coal. Further motivation for adopting sustainable levels of energy consumption and renewable fuels is provided by the linkage between energy use and greenhouse gas (GHG) emissions, climate change, and energy security (Subhadra, 2011). Biofuels can offset a portion of liquid petroleum-based fuels; however, sources of biofuel feedstock are limited and compete for arable land with food crops. Crop and plant oil sources, such as soybean, sunflower, and oil palm, have annual oil productivities of 449, 954, and 5940 L ha⁻¹ yr⁻¹, respectively (USDOE, 2010).

Microalgae are receiving a lot of attention as a potential renewable energy source, replacement for some portion of fossil fuels, and possible means for reducing carbon dioxide (CO₂) emissions (Day et al., 2011; Demirbas and Demirbas, 2011; Mata et al., 2010; Nigam and Singh, 2011; Park et al., 2011; Pittman et al., 2011; Sialve et al., 2009; Singh et al., 2011; Smith et al., 2010;

Subhadra, 2010; Zeng et al., 2011). Some species of microalgae can theoretically attain a much higher oil yield per unit land area than any other known biomass source, with estimates ranging from 9354 to 60,800 L ha⁻¹ yr⁻¹ (USDOE, 2010). However, the upper end of this range has not been approached at a commercial-scale and represents an unrealistic goal with current microalgal cultivation processes. Notwithstanding the over-promotion of oil productivity of microalgae, there are numerous environmental benefits that could be realized in conjunction with biomass or biofuel production. Microalgae growth takes place in nutrient-rich waters; therefore, can also be used to remove unwanted nutrients from wastewater effluent (Pittman et al., 2011; Rawat et al., 2011). A major advantage of using algae as a step in the wastewater cleanup process is that a potentially valuable commodity (e.g., biofuels and bioproducts) can be produced instead of a disposal cost. An additional benefit is that algal biomass is a carbon-neutral fuel source, capable of reutilizing waste CO₂ and reducing net CO₂ emissions. However, the potential of microalgal production systems for reducing GHG emissions is difficult to quantify.

Biodiesel is an important fuel that can be derived from microalgal lipids via transesterification; however, just about any product derived from petroleum can also be derived from microalgal lipids (Subhadra, 2010). A large number of co-products could be generated from the biomass remaining after the algal lipids are converted into biofuel. Some of those co-products include nutrients for pharmaceuticals, fats for nutritional supplements (such as

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