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Nannochloropsis production metrics in a scalable outdoor photobioreactor for commercial applications

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HIGHLIGHTS

- ▶ Growth rates averaged 0.16 g L^{-1} d^{-1} during calendar years of 2009 & 2010.
- ▶ Peak growth rate of 0.37 L^{-1} d^{-1}.
- ▶ Average bio-oil productivity of 10.7 m^3 ha^{-1} yr^{-1} with peak of 36.3 m^3 ha^{-1} yr^{-1}.
- ▶ Serial batch cultures maintained for >421 days of continuous cultivation.
- ▶ Energy consumption sensitivity analysis for large-scale photobioreactor system.

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ABSTRACT

Commercial production of renewable energy feedstocks from microalgae will require reliable and scalable growth systems. Two and one half years of biomass and lipid productivity data were obtained with an industrial-scale outdoor photobioreactor operated in Fort Collins, Colorado (USA). The annualized volumetric growth rates for *Nannochloropsis oculata* (CCMP 525) and *Nannochloropsis salina* (CCMP 1776) were 0.16 g L^{-1} d^{-1} (peak = 0.37 g L^{-1} d^{-1}) and 0.15 g L^{-1} d^{-1} (peak = 0.37 g L^{-1} d^{-1}) respectively. The collective average lipid production was 10.7 m^3 ha^{-1} yr^{-1} with a peak value of 36.3 m^3 ha^{-1} yr^{-1}. Results from this study are unique based on publication of biomass and corresponding lipid content combined with demonstration of energy savings realized through analysis of gas delivery requirements, water recycling from successive harvests with no effect on productivity, and culture stability through serial batch lineage data and chemotaxonomic analysis of fatty acid contents.

1. Introduction

Relative to first-generation biofuel feedstocks, microalgae are characterized by higher solar energy yield, the potential for year-round cultivation in many locations, the ability to grow in brackish and saline water as well as water produced from oil and gas extraction, higher areal productivities than oil seed crops and the utilization of non-arable land (Batan et al., 2010; Chisti, 2007; Li et al., 2008; Williams et al., 2009). Microalgae can grow in poor-quality water, utilize CO_2 from point sources such as coal fired power plants and utilize nutrients from wastewater treatment plants with a uniquely high productivity potential (Chisti, 2008a; Li et al., 2008; Schenk et al., 2008; Wijffels and Barbosa, 2010). Current lab-scale experimental data have suggested a near-term realizable production an order of magnitude higher than the current productivity of ethanol from corn and bio-diesel from soy: 2533 liters hectare^{-1} yr^{-1} (271 gal acre^{-1} yr^{-1}) of ethanol from corn and 584 L ha^{-1} yr^{-1} (62.5 gal acre^{-1} yr^{-1}) of bio-diesel from soybeans, respectively (Chisti, 2007).

Microalgae cultivation is typically done in, open raceway ponds or photobioreactor systems. The two primary advantages of photobioreactors are increased culture stability resulting from lower likelihood of pathogen or grazer infestations and higher volumetric productivities due to differences in light utilization. These advantages have led to an interest in photobioreactor technology for the

Abbreviations: AGS, Algae Growth System; CCMP, Center for Culture of Marine Phytoplankton; DW, Dry weight; FAME, Fatty acid methyl ester; GC, Gas chromatograph; LCA, Life Cycle Analysis; VVM, Volume of air per volume of culture per minute.

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