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Harvesting economics and strategies using centrifugation for cost effective separation of microalgae cells for biodiesel applications

Adam J. Dassey, Chandra S. Theegala *

Department of Biological and Agricultural Engineering, Louisiana State University, 161 EB Doran Bldg., Baton Rouge, LA 70803, USA
Louisiana State University Agriculture Center, Baton Rouge, LA 70803, USA

HIGHLIGHTS

- ▶ A new strategy for minimizing microalgal harvesting costs was developed.
- ▶ Lower harvesting efficiencies with higher flow rates were more cost effective.
- ▶ Centrifugation can potentially be a primary harvesting technique.
- ▶ Energy consumption and costs for various algal densities and lipids are provided.

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ABSTRACT

Inefficient or energy-intensive microalgal harvesting strategies for biodiesel production have been a major setback in the microalgae industry. Harvesting by centrifugation is generally characterized by high capture efficiency (>90%) under low flow rates and high energy consumption. However, results from the present study demonstrated that by increasing the flow rates (>1 L/min), the lower capture efficiencies (<90%) can be offset by the larger volumes of culture water processed through the centrifuge, resulting in net lower energy consumption. Energy consumption was reduced by 82% when only 28.5% of the incoming algal biomass was harvested at a rate of 18 L/min by centrifugation. Harvesting algal species with a high lipid content and high culture density could see harvesting costs of $0.864/L oil using the low efficiency/high flow rate centrifugation strategy as opposed to $4.52/L oil using numbers provided by the Department of Energy for centrifugation harvesting.

1. Introduction

Algae are a potentially viable and competitive fuel crop because of their high per-acre productivity, absence of competition with feed/food-based products, use of otherwise non-productive, non-arable land, utilization of a wide variety of water sources (fresh, brackish, saline, and wastewater), mitigation of greenhouse gases released into the atmosphere, and production of both biofuels and valuable co-products (Pienkos and Darzins, 2009). With some species containing lipid contents as high as 70% of the cell's biomass, microalgae could potentially produce nearly 136,900 L/ha of biodiesel per year as compared to soybean which is capable of only 446 L/ha (47 gal/ac) per year (Chisti, 2007); however, trials under ideal conditions have shown that fast-growing microalgae can only yield 16,828–18,168 L/ha/year (1800–2000 gal/ac/year) (Um and Kim, 2009).

Given the relatively low biomass concentration obtainable in microalgal cultivation systems, marginal density difference with culture water (average ~1020 kg/m^3), and the small size of microalgal cells (5–50 μm in diameter), costs and energy consumption for biomass harvesting are significant concerns that needs to be addressed properly (Li et al., 2008; Pieterse and Cloot, 1997). Depending on species, cell density, and culture conditions, harvesting algal biomass has been estimated to contribute 20–30% to the production cost (Gudin and Thepenier, 1986).

Such cost estimates are typically associated with the dewatering of microalgae through centrifugation. Continuous flow centrifuge systems allow sediment-bearing water to be pumped continuously through the bowl assembly, forcing particles to the wall while clarified water passes through the overflow (Rees et al., 1991). Quick dewatering of algae is evident with 84% removal efficiency of 0.2 g/L algal culture at a flow of 100 gal/min (379 L/min) under a rotational velocity of 3000 rpm (Kothandaraman and Evans, 1972). Unfortunately, under these conditions the use of centrifuges for algal separation is very energy intensive. The use of centrifugation for harvesting algae cultures from 0.04% to 4% dry

* Corresponding author. Tel.: +1 225 578 1060; fax: +1 225 578 3492.
E-mail address: ctheegala@agcenter.lsu.edu (C.S. Theegala).

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