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Perspective assessment of algae-based biofuel production using recycled nutrient sources: The case of Japan

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HIGHLIGHTS

- Assess the utilization of recycled nutrients to produce biodiesel from algae.
- Compare algal cultivation using open ponds and photobioreactors technologies.
- Compare biodiesel production from two algal species of *Chlorella vulgaris* and *Botryococcus braunii*.
- Algae-to-oil system is not cost effective as an advantage wastewater treatment.

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ABSTRACT

In this study, an upper limit in the solar energy conversion efficiency which can be translated to a maximum potential algal yield of a large-scale culture is calculated based on the algal productivity model in which light and nutrient are made the growth rate limiting factors, and taking the design characteristics of the cultivation system into account. Our results indicate that for the production of low-cost biodiesel within the limits of the wastewater quality standards, that the culturing of high lipid content algae within a raceway pond would provide an appropriate solution for manufacturing biodiesel from algae. However, due to inefficient sunlight utilization and due to the large amount of fertilizer required in raceway ponds, a greater effluent recycle rate would have to be implemented to reduce the amount of fertilizer discharge to meet the wastewater quality standards and to maximize the attainable productivity of algal biomass.

1. Introduction

A sustainable development cannot be achieved without the support of robust energy supplies that are steady, cost-effective and low-hazard. Biofuels that can substitute fossil fuels are a hot topic today in many countries around the world. Algae as feedstock for biofuels have been highly regarded for several decades, due to its high biomass productivity and no competition with food supplies (Chisti, 2008; Mata et al., 2010; Sheehan et al., 1998). Despite these advantages, production of algae has larger potential environmental impacts in energy use, greenhouse gas emissions and water use, compared to conventional crops from a life cycle perspective (Clarens et al., 2010; Lardon et al., 2009).

Lardon et al. (2009) and Clarens et al. (2010) have also determined the impacts associated with fertilizer demand for algal cultivation according to the algae composition and life cycle inventory database, respectively, despite there are not many analyses focused on this topic. Their results showed fertilizer demand is a critical challenge for algae-derived biofuel due to the fact that mass algal cultivation requires significant amounts of nitrogen fertilizer, and production of chemical fertilizer is a principal burden driver of greenhouse gas emissions and eutrophication. Utilization of the wastewater as nutrient sources and recycling the spent biomass contained nutrients were suggested as a way to reduce the fertilizer consumptions and nutrient discharges. However, the actual environmental impact of fertilizer discharge may be underestimated since the algal culture must be enriched with nutrients to be viable for commercial purposes. For instance, the ammonium concentrations contained in enrichment media that are suitable for mass production of microalgae in large-scale extensive systems are generally above 100 mg per liter (Lavens and Sorgeloos, 1996), which can increase the fertilizer discharge beyond expected levels.

To mitigate the environmental impact of the consumption of great quantities of energy, anaerobic digestion used for energy recovery from microalgae residues after biofuel production was theoretically estimated in the studies of Chisti (2008), Sialve et al. (2009) and Heaven et al. (2011). The technology for anaerobic digestion using microalgae residues was further experimentally

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