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In situ biodiesel production from wet *Chlorella vulgaris* under subcritical condition

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HIGHLIGHTS

- ▶ The conventional biodiesel production process is not environmentally friendly.
- ▶ Biodiesel can be made directly from wet algal biomass and subcritical methanol.
- ▶ Stirring shortens the reaction time to achieve high conversion yield of FAMEs.

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ABSTRACT

The conventional base catalyzed biodiesel production process uses refined vegetable oil as feedstock oil and is not environmentally friendly. The supercritical methanol technology does not require the use of catalyst but it is energy intensive due to the high temperature and pressure required in the process. In this work, a process was developed for producing biodiesel directly from wet *Chlorella vulgaris* biomass (80% moisture content) using subcritical water as catalyst. Under the following conditions: The ratio of wet biomass to methanol is 1/4 (g/mL), the reaction temperature is 175 °C and after 4 h, the reaction product contained 89.71% fatty acid methyl esters (FAMEs). The yield is 0.29 g FAME per g dry biomass. This is considerably higher than the yield of 0.20 g FAME per g dry biomass obtained when the neutral lipid of *C. vulgaris* biomass was extracted and converted into FAME.

1. Introduction

In order to satisfy the world's energy demand for fuel and decrease the dependence on fossil fuels, research has been directed towards finding renewable, clean and environmentally-friendly alternative energy sources. Biofuel, especially biodiesel, is one such source that is receiving special attention. Oleaginous microalgae are being considered as potential feedstock for biodiesel production. Their rapid growth rate and high intracellular lipid content [1,2] make them a potential candidate for feedstock. *Chlorella* strains have been considered as promising candidates for commercial lipid production due to their fast growth and easy cultivation. In addition *Chlorella* strains are not contaminated by other strains of microalgae when cultivated in open ponds [3].

Although high biomass productivity, rapid lipid accumulation and ability to survive in saline water make microalgae a promising feedstock for industrial-scale biodiesel production. The high cost of producing microalgae biomass and conventional biodiesel production processes make biodiesel production from microalgae biomass uneconomical [4]. The conventional method used for biodiesel preparation from microalgae is to first extract lipids. The lipids are then converted into fatty acid alkyl esters. The extraction efficiency depends on factors such as microalgae species, method of cell wall disruption and solvent used for extraction [5–8]. Cell disruption prior to extraction can increase the amount of extractable oil. The most commonly used physicochemical techniques for microalgal cell disruption include grinding followed by ultrasonication, microwave treatment, autoclaving, bead-beating and sonication [9,10]. However, the oil extraction step is considered uneconomical. Attention is now being focused on direct or *in situ* production of biodiesel from microalgae biomass.

The conventional production of biodiesel uses refined oil (with free fatty acid (FFA) content less than 0.5%). This refined oil reacts with methanol and is catalyzed by alkali. The biodiesel production from microalgae uses alkali as a catalyst. This would not be suitable due to the high FFA content of microalgae lipids. The high FFA concentration leads to soap formation and difficulties in biodiesel purification [11].

Most studies on biodiesel production from microalgae were based on dry algal biomass. It was necessary to remove the water after harvesting biomass. Drying the biomass is energy intensive

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