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Evaluation of hydrolysis–esterification biodiesel production from wet microalgae

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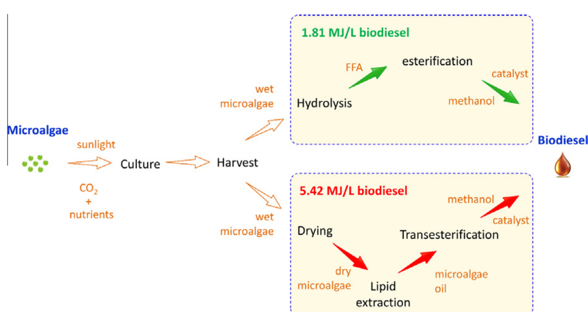
HIGHLIGHTS

- Energy consumption of different microalgae biodiesel production routes is evaluated.
- Vapor recompression and heat integration are utilized to reduce energy consumption.
- Energy requirement of hydrolysis–esterification route is reduced to 1.81 MJ/L biodiesel.
- 3.61 MJ can be saved to produce per liter biodiesel by hydrolysis–esterification route.

GRAPHICAL ABSTRACT



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ABSTRACT

Wet microalgae hydrolysis–esterification route has the advantage to avoid the energy-intensive units (*e.g.* drying and lipid extraction) in the biodiesel production process. In this study, techno-economic evaluation of hydrolysis–esterification biodiesel production process was carried out and compared with conventional (usually including drying, lipid extraction, esterification and transesterification) biodiesel production process. Energy and material balance of the conventional and hydrolysis–esterification processes was evaluated by Aspen Plus. The simulation results indicated that drying (2.36 MJ/L biodiesel) and triolein transesterification (1.89 MJ/L biodiesel) are the dominant energy-intensive stages in the conventional route (5.42 MJ/L biodiesel). By contrast, the total energy consumption of hydrolysis–esterification route can be reduced to 1.81 MJ/L biodiesel, and approximately 3.61 MJ can be saved to produce per liter biodiesel.

1. Introduction

Biofuel is a promising alternative of fossil fuels due to several advantages, sustainability, environmental friendly and good adaptability (Chen et al., 2015; Su et al., 2015). Among different biofuels, biodiesel has attracted the most interest. However, the first and second generation biodiesel is difficult for commercial application owing to their influence on food security, instability and high production cost (Noraini et al., 2014; Rawat et al., 2013). In light of the challenge, microalgae have been considered as a more viable feedstock for biodiesel without displacing crops and land (Chisti, 2007; Alaswad et al., 2015).

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Generally, biodiesel production from microalgae includes culture, harvesting, drying, extraction and transesterification (Khoo et al., 2013; Bahadar and Khan, 2013). Although microalgae biodiesel production presents significant potential, it still has several challenges that must be overcome. Heretofore, cost is the main hurdle to commercialization of biodiesel product (Ma and Hanna, 1999; Song et al., 2015, 2016). Zhang et al. reported that biodiesel usually costs over 0.5 \$/L, compared to 0.35 \$/L for petroleum-based diesel (Zhang et al., 2003). The life-cycle assessment (LCA) by Lardon et al. indicated that high biodiesel from algae production cost was mainly caused by microalgae drying and lipid extraction, which accounted for up to 90% (Lardon et al., 2009). In addition, the presence of free fatty acids and water adversely causes saponification reaction during transesterification of triglycerides, which also causes additional energy input for pretreatment before reaction (Kusdiana and Saka, 2004a).

It can be conceived that avoiding microalgae drying and lipid extraction would be an effective alternative to save energy and cost in the biodiesel production processes (Xu et al., 2011; Sathish and Sims, 2012; Takisawa et al., 2013a). Many efforts to eliminate these energy-intensive units have been put forward. In 2004, Kusdiana and Saka designed a two-step biodiesel production process from rapeseed oil (Kusdiana and Saka, 2004b). Hydrolysis and esterification were carried out under the subcritical state of water and methanol, respectively. They found that the hydrolysis–esterification route could convert rapeseed oil to fatty acid methyl esters (FAME) in considerably shorter reaction time and milder reaction condition than the direct supercritical methanol transesterification. In 2013, Takisawa et al. tested hydrolysis of wet microalgae and then esterified the hydrolysates under high water content (Takisawa et al., 2013b). The experiment results indicated that FAME yield by esterification of hydrolysates was increased by 181.7% compared to that by direct transesterification under the same amount of water content (80%). Although a large amount of research has been carried out to develop novel biodiesel production processes, literature

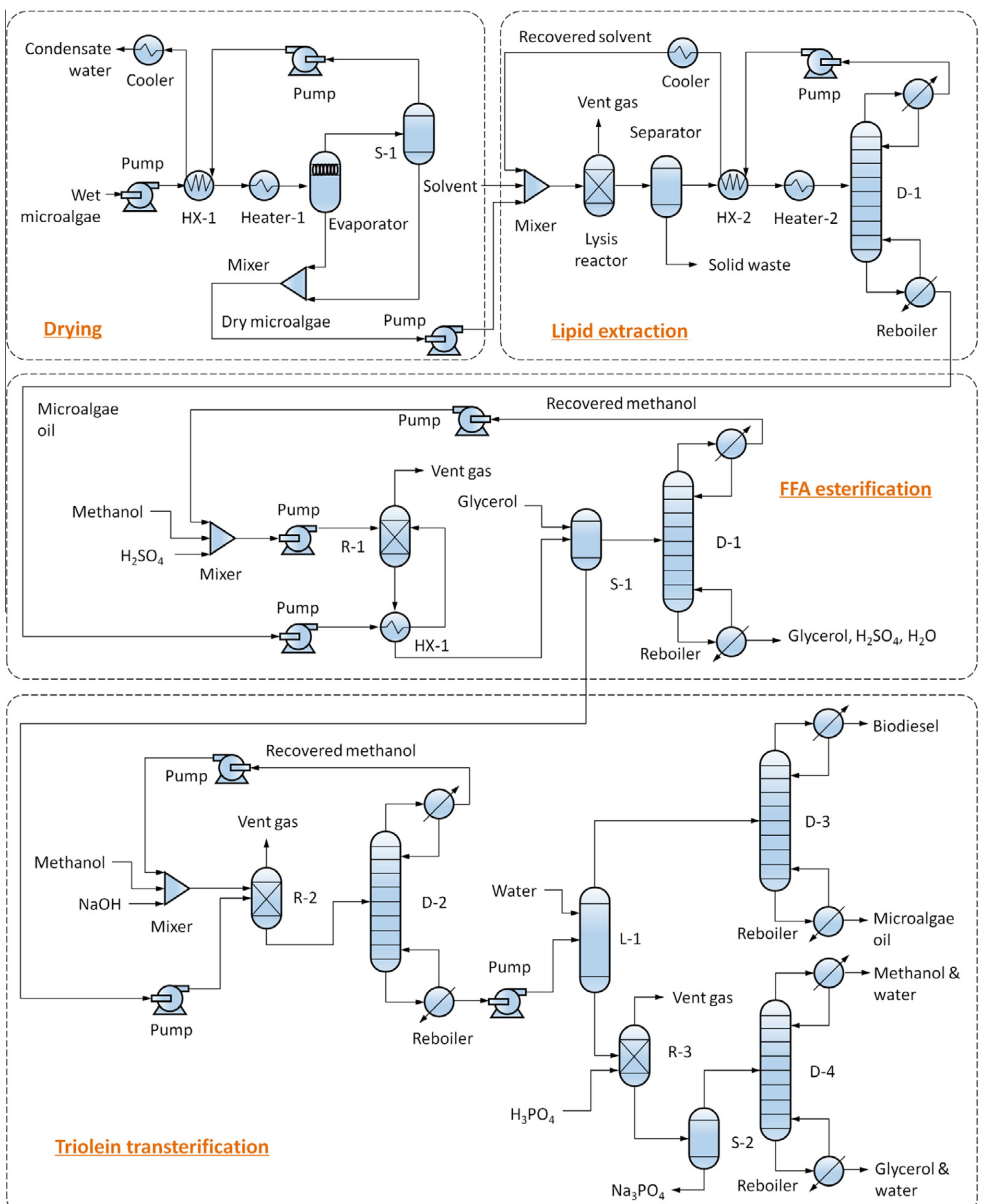

Fig. 1. Conventional biodiesel production process from microalgae by drying, lipid extraction, FFA esterification and triolein transesterification.