Optimization of Hydrolysis and Esterification for Biodiesel Production from Wet Microalgae

(含水微細藻類からのバイオディーゼル生産のための加水分解およびエステル化の最適化)

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Abstract

It has become obvious that continued dependence on fossil fuel is unsustainable because of global warming by greenhouse gas emission and the future depletion of fossil fuel. Development of renewable energy has attracted much interest for energy sustainability. Biodiesel is a renewable fuel which is produced from oils derived from plants, animals or microbes. It is non-toxic and biodegradable, and has lower emission of greenhouse gas when burned in diesel engine. Various methods such as transesterification, blending, cracking, microemulsification and pyrolysis have been developed to convert oil into biodiesel which is comparable to diesel fuel. Transesterification is the most common method for the production of biodiesel and consists of a number of consecutive reversible reactions. Triglyceride is converted stepwise to diglyceride, monoglyceride and finally glycerol and a mole of fatty acid methyl ester (FAME) named as biodiesel is liberated at each step. Generally, alcohol and catalyst are needed for transesterification of oil.

Microalgae are unicellular microscopic (2–200 μm) autotrophic organisms which grow by photosynthesis and are the eukaryotic representatives, though the prokaryotic cyanobacteria are often included in algae. Some species contain more than 70% lipid (dry weight basis). They also grow extremely rapidly under optimal conditions and their growth rates are 100 times faster than terrestrial plants. Oil yield of microalgae containing 70% oil content is 58,700 L/ha year and much higher than other crops (e.g., soybean 446 L/ha year and palm 5950 L/ha year). In addition, microalgal cultivation does not encroach on arable land suitable for food production.

The extraction of lipid from microalgae and their conversion into biodiesel in a single step would be highly valuable as it will bypass the use (and cost) of large quantities of organic solvents. However, such direct transesterification approach has an issue, namely that the existence of water inhibits the reaction. In our study, hydrolysis of lipid to free fatty acid (FFA) from microalgae under high water content was investigated as a pretreatment of direct esterification. Results indicated that the hydrolysis process reduced the inhibition by water in FAME production. Also, FAME obtained by esterification of hydrolysates was increased by 181.7% compared to

FAME obtained by direct transesterification under the same amount of water content (80%). Therefore, it was confirmed that hydrolysis process can reduce the negative effect of water on biodiesel production from wet microalgae.

In addition, hydrolysis of wet microalgal lipid to FFA followed by esterification of FFA using acid in one-step process was investigated. The investigation of simultaneous hydrolysis-esterification (SHE) of wet microalgal lipid was conducted by using L_{27} orthogonal design and the effects of water content, volume of sulphuric acid, volume of methanol, temperature and time on SHE were examined. As a result, water content was found to be the most effective factor. The effects of various parameters on FAME content and equilibrium relation between FAME and FFA were also examined under water content 80%. Equimolar amounts of sulphuric acid and hydrochloric acid showed similar results. When two-step and simultaneous processes were compared, total reaction time in the two-step process was found to be faster than that seen in the simultaneous process. These methods have great potential in terms of biodiesel production from microalgae since no organic solvents are used, simultaneously reducing the drying cost and lowering the operating cost compared to other traditional methods.