Review on direct transesterification method using recent technologies

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Abstract

Nowadays the research is focused on microalgae oil for biodiesel production because of high yield as compared to vegetable plant oil and it fixes carbon dioxide from atmosphere. It is a third-generation biofuel that can easily replace diesel which will deplete in couple of decades and can be used in diesel engine without any modification simultaneously cutting down the engine emissions. The biodiesel production from microalgae is a complex process which includes harvesting, drying, cell disruption, lipid extraction and biodiesel production. However, using direct in-situ transesterification these steps are reduced, and biodiesel production get simplified. Here in this wet algal biomass directly transesterified using alcohol, catalyst and solvents thus eliminating the drying and oil extraction process. This paper reviews the different methods used for direct transesterification in order to reduce the cost of production and increase the biodiesel yield. For cell different techniques are studied and analyzed the best technique from literature review.

1. Introduction

In order to improve efficiency and to reduce pollution from vehicles Microalgae converts water and CO_2 to oil through the photosynthesis (Fu et al., 2010). Few algae species have high oil content in contrast to other edible oil plants and does not used as a edible oil and thus do not compete with food (Schenk et al., 2008). Nowadays research is focused towards algal oil production instead of edible oil (Im et al., 2014). As this is new field of research so there are large number of difficulties to produce biodiesel to larger scale (Halim et al., 2012). Moreover, cultivation as well as oil extraction techniques are still in its initial phase of development as compared to vegetable plant (Halim et al., 2012). Different techniques are used for oil extraction this includes cell disruption followed by lipid extraction using different solvents. Cell walls of algae are disrupted by the use of microwave, ultrasonic reactor as well as chemically, the first two techniques consume large amount of energy because it's very difficult to break very strong wall. In case of presence of moisture in biomass during transesterification the yield get reduced significantly (Hidalgo et al., 2013). To overcome the above given problem the oil extraction from wet algae biomass using advance technique was recommended. It was observed that the biodiesel production from algae is a complex process thus Hidalgo et al., 2013 suggested direct transesterification which saves time and loss of oil during oil extraction process. In direct transesterification esterification and transesterification were simultaneously performed on either wet or dry algae biomass. Direct transesterification reaction requires alcohol, solvent and catalyst for completion of reaction. Singh et al., 2017 used methanolic HCl for direct transesterification of microalgae and fond that methanolic HCl solves the purpose of both catalyst as well as solvent and biodiesel yield was improved. This paper reviews the different advance techniques used for biodiesel production from (wet and dry) microalgae by direct transesterification method.

2.Cell disruption of microalgae

After harvesting the algal biomass, the cells are disrupted using different methods according to the cell wall mechanically or chemically. Cell disruption method helps in extracting contents from the cell and make it easy to interact it with the solvents during oil extraction. The lipid amount obtained from dry algal biomass is always higher than the wet algae biomass lipid extraction (Guldhe et al., 2014). During wet algae oil extraction the moisture in the algae form a layer in between solvent and cell wall that does not allow the solvent to interact with oil thus reduce the lipid content. Thus, it is the necessary to disrupt the cell wall during direct transesterification of wet algae biomass. So different methods were suggested by various researchers according to the cell wall structure of algae biomass.

High-pressure homogenization (HPH) can be used for cell disruption using shear force. This method can be used to disrupt the cell wall of wet algae biomass (Samarasinghe et al. 2012). According to Mata et al., 2010 the cell wall of algae Crypthecodinium cohnii is easily disrupted with the help of ultrasonic reactor the biodiesel yield was increased from 4.8% to 25.9%. Thus, it was concluded that use of ultrasound increases the mass transfer that makes easy for solvent to enter into the cell and extract oil.

3.Direct transesterification

Different works were performed on dry algal biomass to enhance the yield of biodiesel though direct transesterification. Mostly alcohol and sulfuric acid were used for transesterification, these both helps in lipid extraction and esterification, methanol solves the purpose of solvent and esterification. Sometimes additional solvent non polar can be used as a solvent this helps in increasing the contact of algae biomass with the methanol or ethanol (Cao et al., 2013). During the direct transesterification of wet algal biomass several issues are arises, FAME formed during transesterification converted back to alcohol and fatty acid because of the presence of excess moisture that hydrolyze it. Presence of moisture prevents oil extraction due to the formation of layer, and affect the activity of acid catalyst in the reaction. As the presence of water slows the reaction and lower the biodiesel yield. But few researchers have worked on various parameters to increase the yield. Velasquez-Orta et al., 2013 worked on two different microalgae species and varies water content up to 10% using acidic and basic catalyst it was found that using acid catalyst the yield was increased as compared to alkaline catalyst. Wahlen et al., 2011 found high yield during direct transesterification due to the esterification of fatty acid is from phospholipids and TAGs transesterification. The yield of biodiesel decreases with increase in water content, and increase with increase in alcohol content. Im et al., 2014 worked on Nannochlorpsis species and found that at 65% moisture in algal biomass 91.1% conversion yield was obtained when sulphuric acid and methanol and chloroform were used as a catalyst, alcohol and solvent.

4. Advanced approaches of direct transesterification process

Many researchers suggested microwave assisted direct transesterification which helps in reducing the time of completion of reaction and increase the biodiesel yield. In microwave heating the algae cell wall disrupted because of high temperature and pressure inside the cell the experimental setup of microwave is shown in Figure 1 (Patil et al., 2011). Moreover, methanol will absorb the microwave radiation and changing its dipole thus helps in mixing the alcohol and oil thus increase the mixing which helps in increasing the rate of reaction thus reducing the time (Hidalgo et., 2013). Cheng et al., 2013 worked on chlorella species which is 20% dry, and found that using microwave for cell disruption the biodiesel yield was increased 6 times as compared to other heating method.

Patil et al., 2011 also performed direct transesterification using microwave assisted transesterification and high yield was obtained at 800 W. Some researchers also suggested ultrasonic reactor to disrupt the algae cell wall. In ultrasonic reactor the bubbles are formed and collapsed, due to formation and collapsing of bubbles leads to proper

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mixing the two immiscible fluids and thus increases the rate of reaction (Ehimen et al., 2012). Ehimen et al., 2012 obtained 99.9%

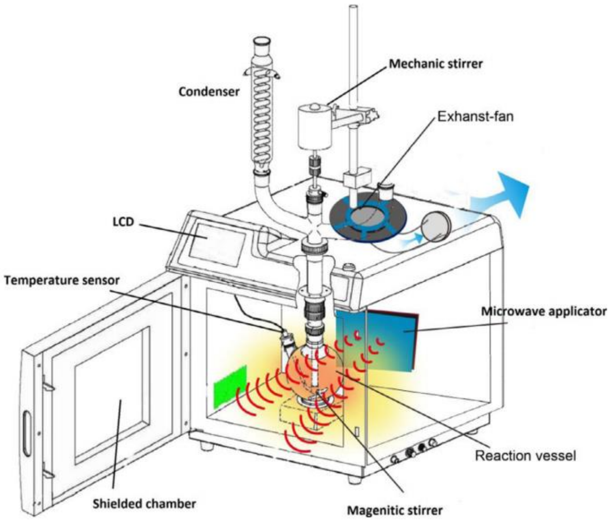

Fig. 1: The microwave assisted transesterification setup by Lin et al., (2014)

conversion using ultrasonic reactor. Tran et al., 2013 carried experiments on chlorella species having water content up to 91% assisted with ultrasonic reactor for cell disruption it was observed that 95.7% yield was obtained using enzyme as a catalyst where hexane was used as a solvent. Mostly, sulfuric acid was used as a catalyst because most of the algae oil have higher free fatty acid thus esterification reaction requires acidic catalyst. However, some researches utilized basic catalyst for direct transesterification. Koberg et al., 2011 and Patil et al., 2011 utilized alkaline catalyst such as SrO and KOH for direct transesterification.

5.Conclusions

This paper reviews the literature related to direct transesterification of algal biomass. Study revels that direct transesterification is simplified process of transesterification in which esterification and transesterification takes place simultaneously. This paper also through light on the different type of catalyst used for transesterification and find that highest biodiesel yield was obtained utilizing acidic catalyst. However, few researchers obtained high yield using alkaline catalyst also. Finally, this paper discuss the direct transesterification assisted with microwave and ultrasonic and obtained that the yield increase 6 fold as compare to simple conventional heating method.

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