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Production of Biodiesel by Transesterification of Algae Oil with an assistance of Nano-CaO Catalyst derived from Egg Shell

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Abstract: Biodiesel is considered as one of the prime sources of non-conventional transportation fuels. Though there are various sources available for biodiesel production, algal oil holds importance since it is non-edible and abundantly available. In this study, we carried out transesterification of oil extracted from river algae using nano calcium oxide catalyst. Nano calcium oxide catalyst was produced by calcinating egg shell powder with sonochemical reactor. Algae biomass were collected from hotels, dried, crushed and sieved for uniform sized particles. Transesterification experiments were carried out using extracted oil from algal biomass using hexane as a solvent. Effects of oil to methanol ratio, temperature and catalyst loading were analyzed and the optimum values were determined. FAME analysis was done to qualify and quantify the biodiesel yield. Experimental results showed that algal oil is a good source of oil and nano CaO catalyst is an effective catalyst for transesterification.
Keywords: Transesterification, nano CaO catalyst, FAME analysis.

Introduction

Energy consumption is inevitable for human existence. The criteria for searching alternative fuel are technically feasible, environmentally acceptable, economically competitive and readily available. The first foremost reason is the increasing demand for fossil fuels in all sectors of human life, such as transportation, power generation, industrial processes, and residential consumption[1]. Depletion of world petroleum reserves and their impact on environment have led to the search for suitable alternative fuels to meet the demand[2]**.** The fabrication of algae biodiesel has gained a good interest over recent years[3]; there by using an effective catalyst the extraction of lipids from the algae can be easily improved[4,5].

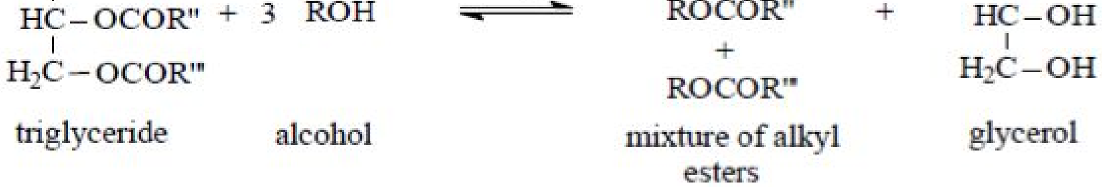

Figure 1 General equation of transesterification

Transesterification, also called alcoholysis, is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis, except that an alcohol is employed instead of water. Suitable alcohols used in transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol[6]**.** Methanol and ethanol are utilized most frequently for transesterification process. This process has been widely used to reduce the viscosity of triglycerides, thereby enhancing the physical properties of renewable fuels to improve engine performance. Thus, Fatty Acid Methyl Esters (FAME) known as biodiesel fuel obtained by transesterification can be used as an alternative fuel for diesel engines[7]**.** The general equation of transesterification of triglyceride with alcohol is represented in figure 1.

There are several studies available in the production of biodiesel from algae[8] and microalgae[1,9,10]**.** This study differs from others by using the catalyst as nano CaO which is derived from the egg shell for the production of biodiesel.

Materials and Methods

Catalyst Preparation

The egg shell was cleaned to remove interference substances and washed thoroughly with warm water several times. Then it was dried in oven at 105^{o}C, overnight. Crushed and powdered shell was then sieved before being subjected to heat treatment in a furnace.

Collection of Algae

The algal sample collected for this present investigation was collected from the river Palar, near Chengalpet. Algal biomass was immediately washed up with running tap water to remove contaminants present and then sun dried to avoid deterioration of biomass in moisture.

Analytical Methods

The total lipids were determined by extracting the algae with chloroform/methanol (2/1, v/v) and was quantified gravimetrically as percent lipid (on a dry weight basis).The potential of algal biodiesel as an alternate for diesel fuel was investigated with respect to density, ash, cloud point, flash point, pour point, cetane number, gross calorific value, water content and copper strip corrosion, based on ASTM procedures.

Extraction of Algae Oil

The crude extract obtained from the expression process was a mixture of lipids, water and traces of algal biomass. The extraction of lipids from the algal liquid was performed using hexane as a solvent in the separating funnel. During the extraction process the triglycerides enter into solvent layer, which was decanted and preserved for further processing. The triglyceride that was present in the hexane layer was more viscous. The residual algal biomass was subjected to further extraction of triglycerides with the addition of hexane. The aforementioned process was conducted 3-4 times, to achieve a higher yield of extractable liquids from the expressed algae liquid.

Transesterification of Algae Oil

The algal lipid obtained after hexane evaporation was used in the heterogeneous transesterification without further treatment. Transesterification was carried out under varying reaction conditions. Temperature, Methanol to oil ratio and catalyst loading rate were varied in the range of 40 – 70^{0}C, 3:1 to 12:1 and 0.5 - 2 % (Wt.), respectively. Acid value of oil was determined by KOH titration method.

Results and Discussion

Extraction of Oil from Algae Biomass

Hexane was used as a solvent for the extraction of triglycerides from the crude liquid extract of algal biomass. To attain a higher yield of triglycerides, the hexane was added in excess (as high as 2.5 times of that of the crude extract, on a volume basis). At a hexane to crude algal oil ratio of less than 1:1.5, more of the crude lipid oil was determined to be sticking on the container, thereby leading to lower yield. Hence, the volume of crude algal extract to that of hexane was maintained at a ratio of 1:2.5.

Transesterification

The objective of the reaction is to complete the transesterification reaction process, thereby resulting in biodiesel that was low in triglyceride concentration. In the transesterification process, an excess of methanol and nano CaO catalyst was used to ensure maximum transesterification. The completeness of reaction was ascertained by drawing the samples at different time intervals and measuring the acid value. Following the transesterification process, the biodiesel was washed with water, to remove the glycerol from the fuel.

Effect of Temperature

Effect of process temperature on transesterification of algae oil was studied in the temperature range of 40 to 70^{0}C and the results are shown in Fig.1. From the figure, it is evident that the transesterification process was facilitated by increasing the temperature up to 55^{0}C. Further increase in the temperature has not resulted in a good conversion of oil to biodiesel. It is due to the boiling point of methanol which is around 70^{0}C.

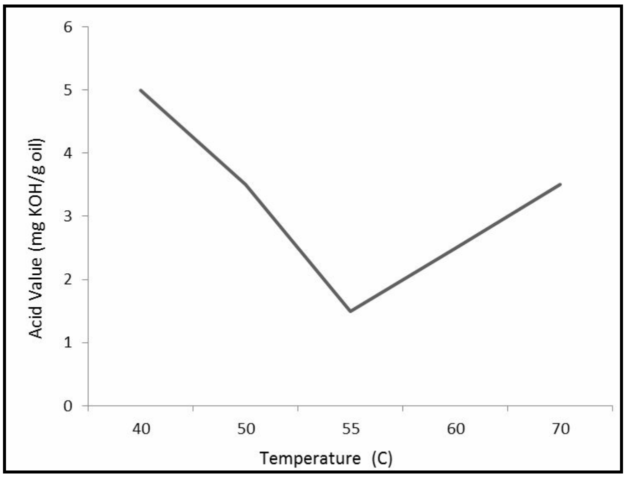

Figure 2 Effect of Temperature on transesterification of algae oil

Effect of Methanol to Oil Ratio

Various methanols to oil ratios were taken in the transesterification reaction of algae oil and the results are shown in Fig.2. Transesterification is the formation of methyl esters of fatty acids present in the algae oil. Methanol is the excess reactant in this reaction, and hence added in excess quantities. In all the ratios tested in this study, 9:1 is considered as optimum, since the acid value of biodiesel derived by the reaction with this ratio is lowest of all. It is clearly noted from the figure, that the acid value was high for lower methanol oil ratios. However, for the ratio of 12:1, the result was similar to that of 9:1. So 9:1 can be considered as an optimum value for good conversion.

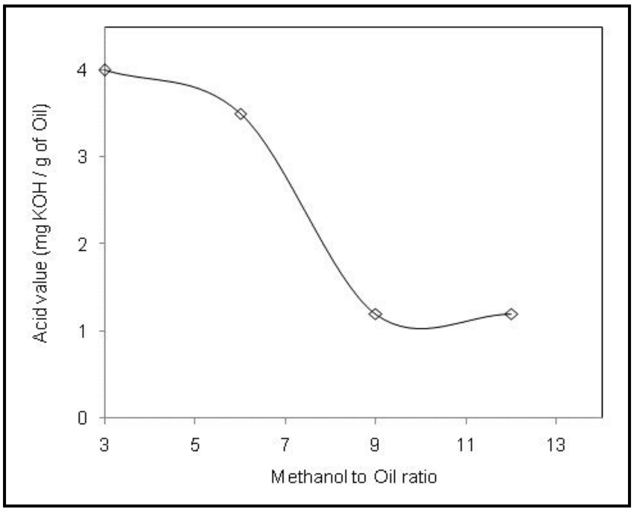

Figure 3 Effect of Methanol to Oil ratio on transesterification of algae oil

Effect of Catalyst Loading

Effect of catalyst loading on transesterification of algae oil was studied at different catalyst loadings and the results obtained are shown in Fig.3.

When the amount of catalyst added was increased from 0.5 to 1.25% by weight, the transesterification was facilitated. Also, when the catalyst loading was increased to 2%, the transesterification was still the same as the previous value.

Catalyst provided necessary surface for the reaction to take place. Increasing the catalyst loading in turn increases the surface area available for the reaction. But, the reaction is limited to the level of reactant available. Therefore, further increase in the catalyst loading may not contribute to the improvement of reaction rate.

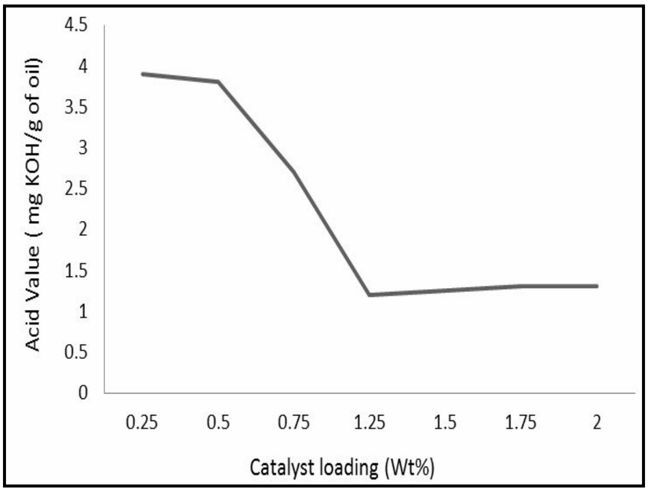

Figure 4 Effect of Catalyst loading on transesterification of algae oil

Biodiesel Yield

To determine biodiesel yield per gram of dry algae biomass, about 1gm of dry biomass was analyzed. Total Fatty Acid (TFA) content was found to be 58.2% of dry biomass i.e., 0.582 gm of TFA was obtained. Under transesterfication, conversion of oil to biodiesel was about 96.3%.on the hole about 55.2% of dry biomass was converted to biodiesel which shows the potential application of algae for the production of Alternate fuels.

Emission Tests for the produced Biodiesel (FAME)

The Biodiesel produced is analyzed for the emission tests and the results obtained are shown above. Fig.4.2 shows the comparative emissions of Biodiesel with the conventional Petroleum-Diesel. The major pollutants in the fossil fuel emissions will normally contain toxic chemical components such as Carbon monoxide (CO), Nitrous oxide (NO_x) and particulate matters (PM). The graph shows clearly that the emissions of those toxic components are limited in the Biodiesel than any conventional Petroleum-Diesel.

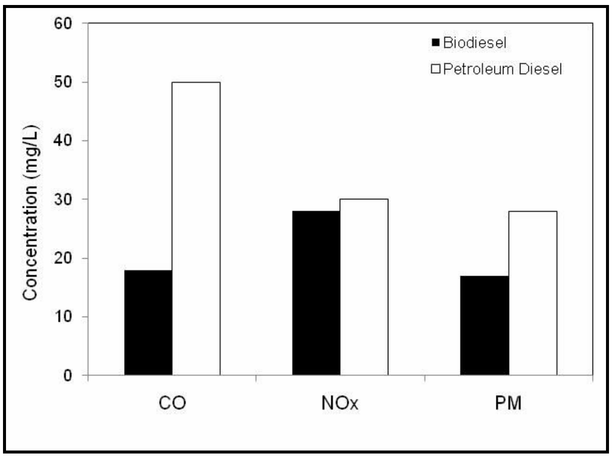

Figure 5 Comparative analyses of Emissions

Conclusions

From this experiment the following conclusions were acquired.

- Egg shell plays as a vital catalyst in the transesterification of algae oil for the production of fatty acid methyl ester, i.e. biodiesel.
- The optimum temperature for the transesterification of biodiesel was found out to be 55^{o}C.
- The optimum methanol to oil ratio was found out to be 9:1 for good conversion of fatty acids present in the algae oil to FAME.
- Effect of catalyst loading on transesterification of algae oil was studied at different catalyst loadings and the results obtained. When the amount of catalyst added was increased from 0.5 to 1.25% by weight, the transesterification was facilitated. Also, when the catalyst loading was increased to 2%, the transesterification was still the same as the previous value.
- The collected algae samples were analyzed for total fatty acids, thus found out to be 58.2% /gm of drier algae.
- The CaO catalyst derived from egg shell makes the process of conversion of algae oil to biodiesel highly efficient, thus 96.3% of oil was converted to biodiesel.

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