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Review of process parameters for biodiesel production from different feedstocks

Puneet Verma*, M.P. Sharma

Biofuel Research Laboratory, Indian Institute of Technology Roorkee, Roorkee 247667, Uttarakhand, India

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ABSTRACT

Biodiesel is one of the prospective alternatives to petroleum fuel resources because of its renewable and environment friendly nature. Transesterficiation process is used for biodiesel production. The biodiesel production process mainly depends on five parameters which includes free fatty acid (FFA) content, type of alcohol used and molar ratio (alcohol:oil), catalyst type and its concentration, reaction temperature and time. Methanol and ethanol are commonly used for biodiesel production in presence of different alkaline catalysts like sodium and potassium hydroxides. The production methodology of biodiesel is an important aspect for efficient and cost-effective production of biodiesel. The present study focuses on the various technical aspects of biodiesel production methodology. The study reveals that for optimum biodiesel production reaction temperature should be in range of 50–60 °C, molar ratio of alcohol to oil should be in range of 6–12:1 with the use of an alkali catalyst having optimum concentration 1% by weight. The optimal reaction time for transesterification process is 120 min.

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* Corresponding author.
E-mail address: itspuneetv@gmail.com (P. Verma).

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1. Introduction

The fossil fuels reserves are rapidly depleting and causing significant environmental degradation all over the world. India's crude oil imports have increased steadily, although, in last fiscal year, rise in imports were marginal due to decrease in international prices of crude oil. Demand for transportation fuels was 124 billion liters in 2015 and is likely to reach 202 billion liters by 2024 [1]. This situation has initiated the research for alternatives to gasoline and diesel. An alternative fuel to diesel must be technically possible, financially reasonable, friendly to environment, and readily available. Biodiesel, a mono-alkyl ester of long chain fatty acids, is a potential substitute of petroleum diesel [2,3]. The edible, non-edible, algal and waste oils are considerable feedstocks for biodiesel production [4–6]. In the light of significant consumption and its imports for food, the focus has shifted to non-edible oils as potential feedstocks. Use of straight vegetable oils (SVOs) directly in engines possess serious engine problems due to high viscosity and reduction in viscosity can be accomplished by transesterification of oil to produce biodiesel that has fuel properties similar to diesel by making use of suitable catalyst [7–9]. The behaviour of transesterification reaction can be studied by kinetic studies which occurs in 3 reversible reaction steps which includes conversion of tri-glyceride (TG) to di-glycerides (DG) and DG to mono-glyceride (MG) and MG to glycerol requiring 3 mol of alcohol. Glycerol is collected as by-product of reaction [10,11]. These 3 steps conversion, being time consuming, complex, can be replaced by one step i.e. kinetics can be monitored with respect to (w.r.t) to methyl ester only which is less costly, less complex and simple to handle. The selection of acid and base-catalysed reactions mainly depends upon free fatty acids (FFAs) composition of parent oil. Base catalysed process can achieve high purity and high yield of biodiesel in a short time (30–60 min) compared to acid catalysed reaction, but is very responsive to the purity of the reactants [12]. Base catalysts mostly used are sodium hydroxide (NaOH), sodium methoxide (CH_3ONa), potassium hydroxide (KOH) and potassium methoxide (CH_3OK) as reported in the literature [13]. The kinetics of reactions for biodiesel production and their usage was examined by different researchers [14–18]. In regards of selection of alcohol, methanol is less costly, has better reactivity and the fatty-acid methyl esters (FAME) produced are more susceptible to evaporate easily than corresponding ethyl esters. But ethanol is less toxic and derived from renewable feedstocks [19]. The present paper reviews the process variables for biodiesel production for optimum biodiesel yield and to understand the effect of different parameters by reviewing kinetics of transesterification reaction.

2. Feedstocks for biodiesel production

There are various prospective raw materials for production of biodiesel. Table 1 depicts the oil sources suitable for biodiesel production.

The non-edible oils feedstocks can be seen as the future sources of biodiesel production compared to edible oils as the latter are competitive to food requirements of people. The former can be obtained from crops cultivated on waste lands in remote areas and demeaned forests. In addition to it, these can be grown on boundaries of agricultural fields, irrigation canals and road sides [17,24].

3. FFA composition of oil feedstocks

FFA present in oils influence the fuel properties of biodiesel significantly and also affect the yield and quality of biodiesel significantly. When FFAs are high (typically $>1\%$), base catalysed reaction cannot be applied directly due to saponification problems but acid–base catalysed process is applicable, in which firstly FFAs are reduced to $<0.5\%$ by acid esterification followed by base catalysed conversion to biodiesel [25]. Issariyakul et al. [17] observed that mustard oil has 1/10th of saturated fatty acids (4.6%) than that of palm oil (42.2%) and so, palm oil was found to be more stable. The extent of saturation and chain length effects the yield and decides the quality of biodiesel. The reason for more stability of palm oil than mustard oil is that former is rich in saturated fatty acids mainly palmitic acid (37.08%), whereas mustard oil is rich in unsaturated fatty acids i.e. oleic (24.98%), linoleic (11.64%), erucic acid (32.81%). Similar observations were made by Nautiyal et al. [18] in *Spirulina platensis* algae and found out that it consists mainly of methyl esters of palmitic acid (41.21%), linolenic acid (17.79%) and linoleic acid (12.64%), with remaining oleic acid, caprylic acid and palmitoleic acid. Vujicic et al. [27] found sunflower oil to get higher poly-unsaturated fatty acids (63.3%) in comparison to saturated (10.6%) and mono-unsaturated (26.1%). Presence of higher unsaturated fatty acids will result good cold flow properties in biodiesel. Based on the literature, FFA composition of different oil feedstocks is given in Table 2.

The data reveals that soybean, mustard, waste cooking, sunflower, rapeseed oil have higher unsaturated fatty acids whereas palm oil and *S. platensis* algae has more saturated fatty acids. The presence of highly unsaturated acids leads to decrease in the stability of biodiesel as it gets oxidised rapidly, whereas existence of exceedingly saturated fatty acids in biodiesel results in poor cold flow properties of biodiesel, thus making it difficult to use biodiesel in cold climatic conditions [35].

Table 1
Feedstocks for biodiesel production [13,20–23].

Edible oils	Non-edible oil	Other sources
Cottonseed oil	Jatropha oil	Microalgae
Coconut oil	Karanja (Pongamia oil)	*Spirulina platensis* algae
Sunflower oil	Mahua oil	Waste cooking oil
Canola oil	Neem	Animal fats
Soybean oil	Eucalyptus oil	Beef tallow
Castor oil	*Linseed*	Poultry fat
Mustard oil	Rubber seed	Fish oil
Peanut oil	Polanga	Chicken fat
Palm oil	Yellow oleander	Chlorella protothecoides microalgae
Rapeseed oil		

4. Fuel properties of vegetable oils

The main problem associated with the use of straight vegetable oils (SVOs) is their viscosity which has to be decreased down to make them usable in engine. This is done mainly with help of transesterification reaction. Table 3 enlists the key properties of different vegetable oils and their comparison with petroleum diesel.

Table 3 explains the various fuel properties of different non-edible oils. The table shows that the kinematic viscosity of oil is quite high and to make it comparable to diesel, therefore oil is converted to biodiesel. In addition to it, feedstocks like waste cooking oil, jatropha, polanga, rice bran oil and chicken fat have very higher acid value/FFA content thus need two step acid–base transesterification process for biodiesel production. Calorific value for the vegetable oil feedstocks is found to be less than that of petroleum diesel. On the other hand Flash point of oils is superior to diesel thus making biodiesel safer for storage. Similarly, other properties are comparable to that of diesel.