Renewable and Sustainable Energy Reviews 14 (2010) 3140–3147

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Biodiesel production from *Jatropha curcas* oil

Siddharth Jain *, M.P. Sharma

Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand 247667, India

ARTICLE INFO

Article history:
Received 12 February 2010
Accepted 19 July 2010

Keywords:
Jatropha curcas oil (JCO) kinetics
Transesterification
Methyl ester (ME)
Fatty acid methyl ester (FAME)

ABSTRACT

In view of the fast depletion of fossil fuel, the search for alternative fuels has become inevitable, looking at huge demand of diesel for transportation sector, captive power generation and agricultural sector, the biodiesel is being viewed a substitute of diesel. The vegetable oils, fats, grease are the source of feedstocks for the production of biodiesel. Significant work has been reported on the kinetics of transesterification of edible vegetable oils but little work is reported on non-edible oils. Out of various non-edible oil resources, *Jatropha curcas* oil (JCO) is considered as future feedstocks for biodiesel production in India and limited work is reported on the kinetics of transesterification of high FFA containing oil. The present study reports a review of kinetics of biodiesel production. The paper also reveals the results of kinetics study of two-step acid–base catalyzed transesterification process carried out at pre-determined optimum temperature of 65 and 50 °C for esterification and transesterification process, respectively, under the optimum condition of methanol to oil ratio of 3:7 (v/v), catalyst concentration 1% (w/w) for H_2SO_4 and NaOH and 400 rpm of stirring. The yield of methyl ester (ME) has been used to study the effect of different parameters. The maximum yield of 21.2% of ME during esterification and 90.1% from transesterification of pretreated JCO has been obtained. This is the first study of its kind dealing with simplified kinetics of two-step acid–base catalyzed transesterification process carried at optimum temperature of both the steps which took about 6 h for complete conversion of TG to ME.

Contents

1. Introduction . . . 3140
2. Literature review . . . 3141
3. Material and methods . . . 3142
4. Experimental procedure . . . 3143
   4.1. Acid pretreatment step . . . 3143
   4.2. Base catalyzed transesterification . . . 3143
   4.3. Sample treatment . . . 3143
5. Results and discussion . . . 3143
   5.1. Kinetics of transesterification of *Jatropha curcas* oil . . . 3144
6. Conclusions . . . 3146
   Acknowledgements . . . 3146
   References . . . 3146

1. Introduction

The growth of industries, transport, agriculture and other human needs depends largely on petroleum fuels and the per capita energy consumption of a nation is the indication of its economic property. In recent years, the fossil fuel resources are depleting rapidly with consequent environment degradation. Further, India is importing more than 80% of its fuel requirement and spending a huge amount of foreign currency on fuel. Before a serious catastrophic stage arrives, it becomes highly imperative to search alternative fuel options based on renewable energy. Biodiesel is becoming more and more important can prove to be a substitute of diesel and can be produced from vegetable oil resources, particularly, non-edible one oil resources [1]. Biodiesel,

* Corresponding author. Tel.: +91 9456382050; fax: +91 1332 273517.
E-mail address: arthjain2001@gmail.com (S. Jain).

1364-0321/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2010.07.047

the monoalkyl esters of long chain fatty acids derived from a renewable lipid feedstocks such as vegetable oil or animal fat, is providing a substitute of or additive to diesel in developing as well as developed countries [2,3]. In India, fuel ethanol and biodiesel are acquiring special importance from energy security and environmental concerns point of view as it can offer large scale employment in the growing and processing of resource particularly in rural areas [4]. The main advantages of biodiesel are its renewability, better quality of exhaust gas emissions, its biodegradability and its contribution to the reduction in CO_2 emissions [5]. The biodiesel can be prepared by transesterification process combining vegetable oils with alcohol in the presence of the catalyst to form fatty acid alkyl esters (i.e., biodiesel) and glycerol [5–22]. Methanol is the most commonly used alcohol for transesterification because of its low cost [3,5].

The transesterification of vegetable oil has been a preferred option for the production of biodiesel due to its low cost and simple method. Refined vegetable oils are the best feedstocks for biodiesel production due to high rate of conversion of pure triglycerides (TG) to FAME in short period of time. The alkali and acid-catalyzed processes have proved to be more practical nowadays. An alkali-catalyzed process can achieve high purity and high yield of biodiesel in a short time (30–60 min), though; it is very sensitive to the purity of the reactants [9–11]. Only well refined vegetable oils with less than 1% (w/w) free fatty acid (FFA) were transesterified by Zhang et al. [12] who compared different processes of biodiesel production and found that alkali-catalyzed process is the simplest one but had a higher raw material cost compared to other processes. For the oils with high FFA contents, either the acid-catalyzed or two-step acid–base catalyzed processes are preferred which requires excess of methanol. In the later case, the first acid-catalyzed step is used to reduce FFA to $<1\%$ (w/w) followed by base catalyzed transesterification for the conversion of TG to ME [12–16].

The consumption of edible oil in India is very high and still the indigenous production does not cope with the consumption and hence considerable amount is imported. There is therefore very little chance of using edible oils for biodiesel production to ensure food security aspect. However, the non-edible oil resources can be feedstocks for biodiesel production. There can be grown on waste/semi arid lands under National Biodiesel Programme of Govt. of India and potential availability of non-edible oils in India is about 1 million ton per year. *Madhuca indica*, *Shorea robusta*, *Pongamia glabra*, *Mesua*, *Mallotus Philippines*, *Garcinia indica*, *Jatropha curcas* and *Salvadova* have been identified as non-edible oil resources. Further, with introducing of fast food centres and restaurants in India, lot of waste cooking oil will be available for conversion to biodiesel. Out of the above resources, JCO has been considered for present study.

Commercially available crude oils and fats contain considerable amount of free fatty acids (FFAs) that react with the base catalyst and form saponified products during base catalyzed transesterification which requires exhaustive and costly purification of the products. The saponification not only consumes the alkali catalyst but also causes the formation of emulsions which create difficulties in downstream recovery and purification of the biodiesel. The oil quality has a direct relationship with the technology of transesterification. The oils having high FFA need different processes for biodiesel production than low FFA oils. Therefore chemical analysis with respect to FFA and their consumption is a must. The JCO was purchased in 2007 and its long storage has resulted in the increase of FFA s and so it puts limitation on its base transesterification. Since, the FFA in JCO is more than 2.0% (w/w), it is necessary to reduce FFA ($<0.5\%$) by esterification using acid-catalyst followed by base alkali-catalyzed transesterification [47]. Transesterification of triglycerides with low molecular weight alcohols catalyzed by homogeneous catalysis is the most used one [50–57].

2. Literature review

Numerous studies have been carried out on the kinetics of transesterification processes, biodiesel purification, fuel properties and use in diesel engine. The current challenges are to reduce its production cost which is still higher than petrodiesel due to higher cost of non-edible oil resources.

The kinetics for both acid and base catalyzed transesterification reaction are reported by many authors. Dufek et al. [23] have studied the acid-catalyzed esterification and transesterification of 9-(16)-carboxystearic acid and its mono and di-methyl esters and reported unequal chemical reactivity for different carboxyl and carboxyl methyl groups. Freedman et al. [24] reported the transesterification of soyabean and other oils with methanol and butanol to examine the effect of alcohol type, the reaction rate constants, catalyst type and concentration. Noureddini and Zhu [25] studied the effect of mixing of soyabean oil with methanol on the kinetics of reaction using one-phase transesterification process and found that the mixing had profound effect on the ME yield. Separate acid-catalyzed, alkali-catalyzed, enzyme-catalyzed, or supercritical transesterification of different oils including JCO has been studied by a number of researchers [26–39]. Diasakov et al. [26] investigated the kinetics of uncatalyzed transesterification reaction of soyabean oil. Kusdiana and Saka [27] reported the results of kinetics of transesterification of rapeseed oil using supercritical method and found that conversion rate of rapeseed oil to biodiesel increases dramatically at reaction temperature of 350 °C with a molar ratio of methanol to oil of 42:1.

Donato et al. [49] carried out analysis for acid-catalyzed homogeneous esterification reaction for biodiesel production from palm oil fatty acids using different concentration of H_2SO_4 and other acids as acid catalysts and methanol and ethanol as alcohol and evaluated the optimum concentration in terms of reaction rates, yield of alkyl ester and activation energies. Asakuma et al. [58] have evaluated the activation energies of transesterification of various triglycerides using Gaussion software and found that the effect of structure of TG on the reactivity is not particularly large. Barnwal and Sharma [3] carried out the techno-economic analysis of biodiesel production from different oil feedstocks and found that pongamia, a non-edible oil, can yield biodiesel @ Rs. 10.50/L compared to diesel (Rs. 22/L) at that time and seasam oil gave costliest biodiesel @ Rs. 54/L. The land requirement for growing Jatropha plants for meeting the requirement of different blends of biodiesel with diesel like B_5, B_{10} and B_{20} were calculated for the buses of Uttar Pradesh State Road Transport Corporation (UPSRTC) and reported in our earlier paper [22,35]. Saiffudin and Chau [38] studied the transesterification of used frying oil with 0.5% NaOH in ethanol using microwave irradiation and found that there is considerable enhancement in the reaction rates. Acid-catalyzed production of biodiesel from waste cooking oil was studied by Zhang et al. [12,16] who reported that transesterification is a pseudo first order reaction requiring large excess methanol yielding biodiesel up to 99%. Further, several authors have used the methods involving costly chemicals and requiring much time and efforts for the analysis of intermediate reaction products during the course of kinetics study of transesterification but Kusdiana and Saka [27] have used % yield of methyl ester as the only parameter to monitor the rate of reaction and that three step conversion from TG-DG, DG-MG and MG-ME has been simplified in terms of conversion of TG to ME.

Khan [36] have developed the quantitative analysis of the product mixture formed during transesterification reaction. Mittelbach and co-worker [37] carried out analysis of glycerol after dramatization with N,O-bis(trimethylsilyl) trifluoro acetamida (BSTFA) directly in vegetable oil methyl ester. Capillary GC was used for the analysis of mono, di and triglyceride in methyl