Energy Conversion and Management 78 (2014) 266–275

Contents lists available at ScienceDirect

Energy Conversion and Management

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

Study of fuel properties of rubber seed oil based biodiesel

Junaid Ahmad [a], Suzana Yusup [a,*], Awais Bokhari [a], Ruzaimah Nik Mohammad Kamil [b]

[a] Biomass Processing Laboratory, Center of Biofuel Biochemical, Green Technology, Department of Chemical Engineering, Universiti Teknologi PETRONAS, Tronoh 31750, Malaysia
[b] Department of Fundamental and Applied Sciences, Universiti Teknologi PETRONAS, Tronoh 31750, Malaysia

ARTICLE INFO

Article history:
Received 24 June 2013
Accepted 24 October 2013
Available online 21 November 2013

Keywords:
FAME
Rubber seed oil
Response surface methodology
Biodiesel properties

ABSTRACT

The scarcity of the fossil fuel, environmental pollution and food crisis are the world's major issues in current era. Biodiesel is an alternative to diesel fuel, environment friendly and biodegradable and is produced from either edible or non-edible oils. In this study, a non-edible rubber seed oil (RSO) with high free fatty acid (FFA) content of 45% were used for the production of biodiesel. The process comprises of two steps. The first step is the acid esterification to reduce the FFA value and the second step is the base transesterification. The response surface methodology (RSM) was used for parametric optimization of the two stage processes *i.e.* acid esterification and base transesterification. The yield of biodiesel was analyzed using gas chromatography. The FTIR (Fourier Transform Infra-Red) spectrum was also determined to confirm the conversion of fatty acid to methyl esters. The fuel properties were analyzed according to the ASTM D6751 and EN14214 and were compared with the previous finding of researchers. All analyzed properties fulfilled the biodiesel standard criteria.

1. Introduction

In the last few decades world scarred by dwindling of fossil fuels and its limited resources for future. The world's energy consumption mainly depends on the liquid and solid fossil fuels. Fossil fuel reserves are few in numbers and they are already reaching their peak production. These non-renewable resource consumption rates are faster than the production. To save the world for future energy crises the renewable energy sources are more attractive option [1]. All the renewable energy technologies are eco-friendly and sustainable. Currently renewable energy source adoption faced hurdles because of economic problems, shortage of supply, and lack of technical aspects [2]. The fossil fuels and their products are the major contributors of the greenhouse gases, global warming, air pollution, incomplete burning of hydrogen, carbon and particulate matter. Renewable energy sources are the ideal solution of these problems [3]. Biodiesel is defined by the ASTM as a liquid fuel that composed of the fatty acid alkyl ester of the long chain fatty acid derived from the vegetable oil and animal fat. Generally there are four major types of feedstock available for the biodiesel production including oil seed (vegetable oil), animal fats, algae and different low quality material such as waste cooking oil, greases and soap stock [1,4]. Biodiesel production at industrial scale mostly utilized oil such as soybean, palm and canola. But the excess use of these vegetable oils (edible oil) leads to food versus fuel crisis. The high cost of biodiesel is one of the major hurdles towards its large scale commercialization. About 80% or more of biodiesel cost is altered by its feedstock price [5]. Present researchers are focusing on the non-edible oil sources for the biodiesel production, such as jatropha, Moringa oleifera, Pongamia pinnata and camelina sativa [6–9].

Current study utilizes the non-edible rubber seed oil for the biodiesel production. Rubber tree (*Hevea brasiliensis*) belongs to the family of euphorbiaceous. The oil content in rubber seed is between 40% and 50% [10]. Malaysia in one of the major rubber producing country in the world, according to Association of Natural Rubber Producing countries with an estimated rubber seed production in Malaysia to be 1.2 million metric tons [11,12]. The rubber seed oil has free fatty acid contents as described by Ramdhas et al. [13]. Rubber seed oil has the potential to be used as biodiesel feedstock for the biodiesel production. Parametric study of the effect of process variables on acid esterification and base transesterification of rubber seed oil was done using the Design Expert 8.0 software. The RSM (Response Surface Methodology) that includes a statistical and a mathematical tool was used to analyze and optimize the reaction parameters. The experimental design employed CCD (Central Composite Design) which is an effective, efficient and economical way of experimental techniques [14]. The present study findings was compared with the previous researchers work and shows better results in terms of the fuel properties.

2. Experimental procedure

2.1. Materials and chemicals

The rubber seed oil was purchased through Kinetics Chemicals (M) Sdn. Bhd. Malaysia and mechanical press technique was adopted to obtain the crude rubber seed oil. All the other chemicals

* Corresponding author. Tel.: +60 53687642; fax: +60 53688204.
E-mail address: drsuzana_yusuf@petronas.com.my (S. Yusup).

0196-8904/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enconman.2013.10.056

and reagents such as anhydrous methanol (99.8%), sulfuric acid (98%) potassium hydroxide (99%) were purchased from Merck Chemicals. The FAME analytical standard was purchased from Sigma Chemicals (USA).

2.2. Rubber seed oil analysis

The basic oil analysis such as the acid value, iodine value, saponification value and peroxide value were performed on the crude rubber seed oil and also treated rubber seed oil by following the AOCS method [15]. The flow chart of the experimental procedure has been described in Fig. 1.

2.3. Acid esterification

Acid esterification is a chemical reaction in which triglycerides (oil) react with lower alcohol such as methanol in the presence of an acid catalyst and reduced the high amount of free fatty acids [16]. In this study sulfuric acid (H_2SO_4) used as the acid catalyst to reduce the FFA content. The process parameters and their ranges are shown in Table 1. The input independent process factors are mainly coded to two levels only which are termed as low and high. These levels are further classified into points called axial points on central composite design. Low factor was coded as −1 and high as +1. The axial factors were coded as −2 and +2.

All experiment was conducted in a 250 ml round bottom three neck flask with a reflux condenser to avoid any loss of methanol. In each run 50 g of oil is heated to desired temperature. Specific amount of methanol and sulfuric acid was added and stirring was done for specific time depending on the experimental plan show in Table 4. After specific time the reaction was stopped and the sample was put into the separating funnel to separate the pre-treated oil and excess of methanol and catalyst. The treated oil was separated and collected for further base esterification process.

2.4. Base transesterification

The acid value of crude rubber seed oil decreased from 84 mg KOH/g to 1.64 mg KOH. The process parameters and their ranges are shown in Table 2. In each run of the transesterification process 50 g of pre-treated oil was used which is mixed with a specific amount of methanol and potassium hydroxide (KOH). Stirring was done for a specific time depending on the experimental plan show in Table 6. After the specified time the reaction was stopped and the sample was put into the separating funnel for separation and left for 24 h. Two layers were formed with the upper layer consisted of methyl ester (biodiesel) and the lower layer was glycerol, methanol and other impurities. The prepared biodiesel is collected after purification and preserved for the analysis of fatty acid methyl ester (FAME) conversion using GC FID.

2.5. Characterization of fuel properties

Rubber seed oil FAME was analyzed qualitatively and quantitatively by using Agilent 7890A GC FID (Gas Chromatography Flame Ionization Detector). The density was measured by using the Anton Paar DMA 4500 M Density Meter in accordance with the testing method of ASTM D 4052. The Perkin Elmer Inc. FTIR was used to analyze the conversion of fatty acid into methyl esters. Viscosity is one of the most important properties of the biodiesel and the viscosity was measured by using Brookfield CAP 200+ following ASTM D 445 method at constant temperature of 40 °C. Cloud point was measured by using the CPP 5G's analyzer by following the ASTM D 2500), Pour point was also measured by using the same equipment by following the ASTM D 97, Cold Filter Plugging Point (CFPP) was determined by using the FPP 5G's analyzer following the ASTM D 6371, Sulfur content was referred to ASTM D 4294, Higher

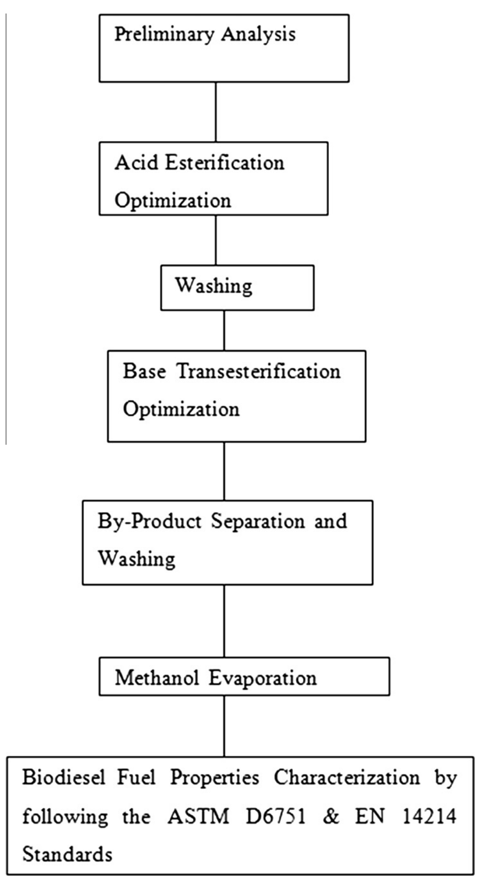

Fig. 1. Flow chart of biodiesel production process.

Table 1
Parameters for acid esterification.

Process parameters	−2	−1	0	+1	+2
Oil to methanol (molar ratio)	8.3	10	12.5	15	16.7
Catalyst concentration (wt.%)	3.3	5	7.5	10	11.7
Temperature (°C)	38.2	45	55	65	71.8
Time (min)	43.1	55	72.5	90	101.9

Table 2
Process parameter for base transesterification.

Process parameters	−2	−1	0	+1	+2
Oil to methanol (molar ratio)	0.95	3	6	9	11.05
Catalyst Concentration (wt.%)	0.16	0.5	1	1.5	1.84
Temperature (°C)	38.16	45	55	65	71.8
Time (min)	29.6	45	67.5	90	105.4

Table 3
Rubber seed oil analysis.

Analysis	Units	Crude rubber seed oil	Treated rubber seed oil
Acid value	mg KOH/g oil	84	1.8
Peroxide value	mg/g	1.6	0.7
Iodine value	g I_2/g oil	146	146
Saponification value	mg KOH/g oil	194	186