Renewable Energy 68 (2014) 414–420

Contents lists available at ScienceDirect

Renewable Energy

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

Technical note

Fuel properties of biodiesel produced from selected plant kernel oils indigenous to Botswana: A comparative analysis

Jerekias Gandure [a,*], Clever Ketlogetswe [a], Abraham Temu [b]

[a] University of Botswana, Mechanical Engineering Department, Private Bag 0061, Gaborone, Botswana
[b] University of Dar es Salaam, Chemical and Mining Engineering Department, P. O. Box 35131, Dar es Salaam, Tanzania

A R T I C L E I N F O

Article history:
Received 13 May 2013
Accepted 12 February 2014
Available online 12 March 2014

Keywords:
Biodiesel
Fuel
Properties
Indigenous

A B S T R A C T

Fuel characteristics of biodiesel derived from kernel oils of *Sclerocarya birrea*, *Tylosema esculentum*, *Schiziophyton rautanenii* and *Jatropha curcas* plants were investigated in comparison with petroleum diesel. The fuel properties under review include flash point, cloud point, kinematic viscosity, density, calorific value, acid value, and free fatty acids. These were determined and discussed in light of major biodiesel standards such as ASTM D 6751 (American Society for Testing and Materials) and EN 14214 (European standards). The best biofuel in terms of cold flow properties was *S. rautanenii*, with a cloud point of 0 °C and a pour point of −5 °C. The good cold flow properties demonstrate operational viability during the cold season. The heating values of *S. birrea* and *S. rautanenii* biodiesel fuels were found to be 9.2% and 10.3% lower than that of petroleum diesel while those of *T. esculentum* and *J. curcas* were both 9.7% lower. Other fuel properties analysed demonstrate that biodiesel fuels produced from kernel oils of *S. birrea*, *T. esculentum*, *S. rautanenii* and *J. curcas* plants have properties that are comparable to, and in some cases better than, those of petroleum diesel. The results of this study indicate the feasibility of producing quality biodiesel fuel from indigenous seed oils found in Botswana. A balanced allocation of resources however needs to be established to ensure that the cultivation of these oil-bearing plants does not compete with the cultivation of food crops.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

The environmental impact of petroleum fuels, coupled with the depletion of known petroleum reserves, make renewable energy sources more attractive and justify the continued search for alternative renewable fuels. Biodiesel is among the renewable energy resources that has attracted considerable attention in recent times. Biodiesel is highly favoured as alternative to petroleum-based diesel because it is renewable, non-toxic, biodegradable, non-flammable and environmentally friendly [1]. Other strengths of biodiesel fuel include its relatively high heat of combustion (lower but closely comparable to that of petroleum diesel), high oxygen value, contributing to combustion efficiency, and minimal contribution to global warming due to its closed carbon cycle [2].

Biodiesel fuel is derived from vegetable oils or animal fats [3]. The transesterification of an oil or fat with a monohydric alcohol, in most cases methanol, yields the corresponding mono-alkyl esters, which are defined as biodiesel. Biodiesel has been produced from various sources that include palm oil [4], rapeseed oil [5], soybean oil [6], and sunflower seed oil [7]. Biodiesel has been characterized according to its properties that include density, viscosity, heating value, acid value, cetane number, cloud and pour points, and flash point. The viability of biodiesel from particular feedstock seed oil depends on such factors as availability of the raw material in commercial quantity, ease of oil extraction, the oil content (yield) of the plant seeds as well as their product (biodiesel) meeting the basic fuel characteristics for diesel fuels.

The successful introduction and commercialization of biodiesel in many countries around the world has been accompanied by the development of standards to ensure high product quality and user confidence. Some of the major biodiesel standards are ASTM D 6751 and the European standard EN 14214.

In the current study, fuel characteristics of biodiesel produced through alkali transesterification of three plant oils indigenous to Botswana and *J. curcas* oil grown under Botswana's natural conditions are compared with those of petroleum diesel.

---

* Corresponding author. Tel.: +267 3554421; fax: +267 3952309.
E-mail address: gandurej@mopipi.ub.bw (J. Gandure).

http://dx.doi.org/10.1016/j.renene.2014.02.035
0960-1481/© 2014 Elsevier Ltd. All rights reserved.

2. Materials and experimental procedure

2.1. Extraction of plant seed oil

Materials used for experimentation include matured seeds (obtained from ripened fruits) of *Sclerocarya birrea*, *Tylosema esculentum*, *Schiziophyton rautanenii* and *J. curcas* plant species harvested from Botswana's indigenous woodlands. In order to maintain oil for experimentation as close to its natural state as possible, mechanical cold press extraction method was used to generate crude oil for subsequent analyses. The mechanism for the extractor consists mainly of a piston, a multi-perforated cylindrical stainless steel compression chamber of approximately 0.15 m diameter and 0.3 m high, and a hydraulic jack system. The schematic diagram of the mechanism is shown in Fig. 1.

Eight kilograms (8 kg) of plant seeds were charged into a multi-perforated stainless steel compression chamber, with stainless steel discs placed at intervals of 2 kg of plant seeds. The piston was located to keep the top disc into position. The hydraulic system was then operated manually to lift up the platform upon which the multi-perforated stainless steel compression chamber sits, thereby compressing the seeds and forcing the oil out of the kernel (seed) and through the 1 mm diameter perforations of the compression chamber. The hydraulic system was operated to a maximum pressure of 30 bars to ensure maximum oil extraction while avoiding over loading the system. The extracted oil was filtered, bottled and kept in a cold room pending conversion to biodiesel as described in Section 2.2.

Solvent extraction was done to establish true kernel oil content (yield) of the four plant species under review, grown under natural conditions. The process involved seed grinding to fine powder, Soxhlet extraction, filtration, distillation and purging. The solvent was prepared by mixing 300 ml of hexane and 100 ml of iso-propyl alcohol in a 500 ml flask. The mixture ensures total extraction of all lipids as hexane extracts all non-polar lipids and iso-propyl alcohol polar lipids. The separation of solvent from the oil was achieved through a distillation process performed using a rotary evaporator. To ensure that no trace of solvent remains in the oil sample, the oil was purged with nitrogen gas (nitrogen drying) for approximately 40 min. Nitrogen is used because it is inert and does not react with oil components.

2.2. Oil characterization

Chemical analysis was performed to establish fatty acid profiles of the extracted oils to evaluate suitability (quality) for use as feedstock for biodiesel production. The method involved analysing standard (reference) samples, generating calibration curves for fatty acids identified in the standard samples, and identifying and quantifying fatty acids present in the extracted oil samples.

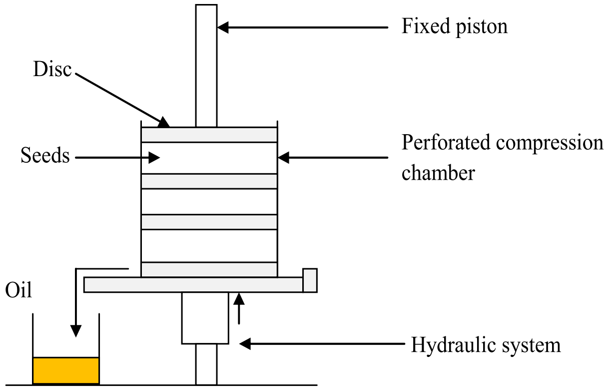

Fig. 1. Schematic of mechanical oil extraction mechanism.

To establish the chemical composition of the standard samples, Arachidate was injected into the standard mixtures as an internal standard (IS) and the samples were run ten (10) times through the Gas Chromatograph - Mass Spectrometry (GC–MS) system at ten (10) concentrations of equal interval from 10 ppm (parts per million) to 1 ppm. At each concentration, peak areas and retention times for all fatty acids present were captured from the chromatogram. Peak area ratios (Analyte/IS) were calculated for all fatty acids present at all concentrations, and these were used to generate calibration curves for each fatty acid in the standard samples. The oil samples were also run through the GC–MS system under similar conditions and peak area ratios (Analyte/IS) calculated for each fatty acid detected. The instrument used for composition analysis is the Waters GCT premier Time of Flight (TOF) mass spectrometer (MS) coupled to the Agilent 6890N gas chromatograph (GC) system. In addition, the National Institute for Standards and Technology (NIST) developed Automated Mass Spectral Deconvolution and Identification System (AMDIS) software package, (chemdata.nist.gov/massspc/amdis) was used for peak identification. The AMDIS extracts spectra for individual components in a GC–MS data file and identifies target compounds by matching these spectra against a reference library, in this case the NIST library.

2.2.1. Gas chromatograph conditions

One micro litre (1 μl) of oil sample extract was injected into the system using an auto-injector. The injector temperature was set at 260 °C in the splitless mode. Helium was used as the carrier gas at a flow rate of 1 ml/min. Separation was achieved using a 30 m DB5 – MS column. The oven temperature was kept at the initial 100 °C for 2 min, and then gradually increased from 100 °C to 290 °C at a rate of 10 °C per minute. The total run time was approximately 35 min.

2.2.2. Mass spectrometer conditions

The mass spectrometer (MS) conditions that were employed were a positive polarity of electron ionisation (EI), a source temperature of 180 °C, and an emission current of 359 μA. Other MS conditions including electron energy and resolution were set by the system's auto tune function. Detection was by the micro channel plate detector (MCP) whose voltage was set at 2700 V. The sample composition was identified and quantified using the NIST (2005) mass spectral library using a combination of the Masslynx acquisition/data analysis software and the AMDIS by NIST.

The procedure described in Section 2.2 was also used to characterize biodiesel samples in order to identify and quantify methyl esters present in biodiesel samples.

2.3. Biodiesel preparation

Biodiesel was produced through an alkali catalysed transesterification process in the laboratory under strict observation and controlled conditions. One litre of crude plant oil was filtered and pre-heated to approximately 105 °C for about 10 min to eliminate water. The oil was allowed to cool to approximately 58 °C and then charged to a 2 L transparent reactor. A solution of methanol of 99.5% purity and 7.5 g of potassium hydroxide pellets of 98% purity as catalyst was prepared and mixed until all the pellets had dissolved in methanol, and then charged to the reaction vessel. The molar ratio of methanol to oil was fixed at 1:6, which is optimal ratio for the transesterification of vegetable oils

Download English Version:

https://daneshyari.com/en/article/300147

Download Persian Version:

https://daneshyari.com/article/300147

Daneshyari.com