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Schleichera oleosa L oil as feedstock for biodiesel production

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HIGHLIGHTS

- *Schleichera oleosa* L oil as the potential resource for biodiesel production.
- The optimization using four different catalysts for transesterification process.
- The optimum ester yield obtained was 96 by KOH.
- The properties of *Schleichera oleosa* L biodiesel satisfied with ASTM D6751 specifications.

GRAPHICAL ABSTRACT

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ABSTRACT

The non-edible oil from *Schleichera oleosa* possesses the potential as a feedstock for biodiesel production. In this study, the biodiesel production was performed using two-step transesterification process on a laboratory scale. The parameters studied were reaction temperature, molar ratio of methanol to oil, catalyst concentration, reaction time and catalysts type. An analysis of variance (ANOVA) was used to determine the methyl ester yield. The optimum conditions were obtained as follows: reaction temperature at 55 °C, methanol to oil molar ratio of 8:1, 1 wt.% of hydroxide catalyst (KOH and NaOH) and 1 wt.% methoxide catalyst (CH_3OK and CH_3ONa) for reaction time 90 min. Based from these optimum conditions, the observed ester yields from different catalysts were average 96%, 93%, 91% and 88% for KOH, NaOH, CH_3OK and CH_3ONa respectively as the catalyst. *S. oleosa* methyl ester (SOME) exhibited a satisfying oxidative stability of 7.23 h and high cetane number (50.6) compared to petrol diesel (49.7). Besides, SOME has good pour and cloud point of −3.0 °C and −1.0 °C respectively due to high unsaturated fatty chain. As a conclusion, this study reveals that biodiesel production from SOME, as one of non-edible feedstock, is able to be an alternative for petrol diesel. Moreover, the produced biodiesel from SOME could be used in diesel engine without major modification due to its properties and can be used in cold regions.

1. Introduction

Recently, the rise of petroleum consumption in industrial, transportation and technology developments has been leading to depletion of the limited fossil fuel resources in the world.

Abbreviation: ASTM, American society for testing and materials; CIME, *Calophyllum inophyllum* methyl ester; CSSO, crude *Schleichera oleosa* oil; EN, European standard; KME, *Kesambi* methyl ester; SME, *Schleichera* methyl ester; SOME, *Schleichera oleosa* methyl ester.

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Because of this, researchers have been putting more attention to find alternative energy such as biodiesel which is believed can lower the dependency of fossil fuel and to support the environmental sustainability [1,2]. Biodiesel can be produced from various vegetable oils and animal fats. However, the feedstock types, availability and material cost are the obstacles to the commercialization of biodiesel production.

There are oil and fat feedstock distribution for top ten developed countries such as animal feedstock (52%), rapeseed (11%), soybean oil (20%), sunflower oil (5%), palm oil (6%), and others vegetable oils (5%) that are identified as potential resources for biodiesel production [3]. This is because edible oils have high yield of biodiesel and they are easily processed (transesterified) due to their lower free fatty acids [4]. In contrary, the use of edible oils has given problems such as serious destruction of vital soil resources. Moreover, the prices of edible oil plants have increased dramatically in the last ten years which have affected the economic viability of biodiesel industry [3,10]. Therefore, many studies have been performed in exploration of non-edible oil which also is able to reduce the production cost and solving the food vs. fuel issue [5,6]. Many researchers, in the last decades, have focused and promoted commercialization of biodiesel as well as low cost from non-edible oils that are grown in forest and unused land such as *Jatropha curcas*, *calophyllum inophyllum*, *Moringa oleifera*, *Eruca sativa gars*, *Croton megalocarpus*, *Cerbera odollam*, *Terminalia*, *Madhuca indica*, *Pongamia pinnata*, *Guizotia abyssinica* and *Neem*. These feedstocks are considered as potential alternative to biodiesel production [7,8].

This study is aimed to investigate the biodiesel production from *Schleichera oleosa* oil, as the promising non-edible feedstock, using four types of homogeneous alkaline catalysts: KOH, NaOH, CH_3OK and CH_3ONa. Then, the fuel properties of the obtained biodiesel were analyzed according to ASTM and EN method.

2. Description of *S. oleosa*

S. oleosa is belonging to *Sapindaceae* family and also known as Kusum fruit. *S. oleosa* is widely found in the sub-Himalayan region, throughout central and Southern India, Burma, Ceylon, Java and Timor. The oil obtained from its seeds is called Kusum oil or Macassar oil, which categorized non crops food and used for the cure of itch, acne and burns [9,10]. The flowers are yellowish green, fascicled in spike like axillary racemes 7.5–12.5 cm long. The fruits are berry, globose or ovoid, and hard skinned [10]. The seeds are brown, irregularly elliptic, slightly compressed, oily, enclosed in a succulent aril [11]. The oil content of the seed is around 59–72% with yellowish green color.

3. Materials and methods

3.1. Extraction of *S. oleosa* oil

The extraction of crude *S. oleosa* oil (CSOO) was done by using a screw extruder machine. Additional process by hydraulic manual pressing machine was performed to increase the oil yield from CSOO which repeated for several times. The *S. oleosa* seeds were afterward sun dried for one week then cleaned. Seed samples were cooked in an oven for 2 h then were pressed with four replications in the screw press oil expeller at an optimum screw-speed of 120 rpm. At each of test conditions, crude oil and cake were collected and weighed. The remained cake was wrapped with a filter and placed inside the press machine. The extraction with press machine was done several times and after the predetermined time, the extraction process stopped. The oil yield of CSOO was calculated by the following equation:

$$\text{Oil yield} = \left(\frac{O_{so}}{W_{so}}\right) \times 100\% \quad (1)$$

where, O_{so} = the extracted weight of *S. oleosa* oil (g), W_{so} = the weight of *S. oleosa* seed (g).

3.2. Reagents and chemicals

Methanol (reagent grade), phospohoric acid, sulphuric acid, potassium hydroxide, sodium hydroxide, potassium methoxide, sodium methoxide, sodium sulfate, calcium chloride were purchased from Metta Karuna Enterprises, Kuala Lumpur, Malaysia. These chemicals were analytical grade (99.98%) chemicals and were used as received without any further purification.

3.3. Experiment set up

In this study, a small scale laboratory reactor consisting of 1 L double-jacketed condenser (functioned to recover methanol), thermometer and motor stirrer was used to produce biodiesel from CSOO.

3.4. Properties of CSOO and methyl ester

Fuel properties of biodiesel are dependent on the fatty acid composition (FAC) of the oil. In this study, physical and chemical characteristics of crude oil and methyl ester produced are analyzed. Besides, the fatty acid oil profile was determined by GC model number Agilent 7890 with flame ionization detector. The column was packed with ZB-wax 30 m capillary column (inner diameter 0.25 mm, film thickness 0.25 μm, split 1:20). The carrier gas was high-purity hydrogen where injector and detector temperatures were 250 °C. Oven temperature was maintained at 100 °C for 10 min, then was increased by 15 °C/min and held at a final temperature of 240 °C for 15 min. The physical, chemical properties and fatty acid compositions of fuel were analyzed as per the standard methods. The FAME content was calculated using the following equation:

$$\text{FAME} = \frac{(\sum A) - A_{EI}}{A_{EI}} \times \frac{C_{EI} \times V_{EI}}{m} \times 100\% \quad (2)$$

where FAME = fatty acid methyl ester content (%); $\sum A$ = total peaks area of fatty acid methyl ester; A_{EI} = area of the peak corresponding to internal standard, methyl heptadecanoate; C_{EI} = concentration of methyl heptadecanoate solution in heptane (mg/ml); V_{EI} = volume of methyl heptadecanoate solution (ml); m = mass of biodiesel sample (mg). Ester yield is defined as follows:

$$\text{Ester yield} = \frac{\text{FAME} \times B_{so}}{O_{so}} \times 100\% \quad (3)$$

where FAME = fatty acid methyl ester content (%); B_{so} = weight of *S. oleosa* biodiesel (g); O_{so} = weight of crude *S. oleosa* (g).

3.5. Optimization analysis

The statistical analysis was carried out with Expert 8.0.7.1 (Stat-Ease, Inc) software and the experimental optimization was obtained by analysis of variance (ANOVA). Optimization of the transesterification process was conducted by four experiment factors to examine the effects of reaction methanol to oil molar ratio, temperature, reaction time and catalyst concentration on the yield of biodiesel. Range and levels of the investigated variables are listed in Table 1.

The factors were temperature (X_1), KOH catalyst concentration (X_2), methanol to oil molar ratio (X_3) and reaction of time (X_3). The upper temperature level, 65 °C, was chosen as the boiling point