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ORIGINAL RESEARCH ARTICLE

Properties and performance of microemulsion fuel: blending of jatropha oil, diesel, and ethanol- surfactant

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To assure energy security source, a renewable nonedible plant such as *Jatropha curcas* oil (JCO) is attractive as a feedstock. However, the high viscosity of this vegetable oil is the main limitation on its fuel properties and makes it unsuitable for direct application in current diesel engines. Microemulsification is an alternative method for fuel production that reduces the by-products from the transesterification process. In this research, microemulsion fuels (MFs) were produced from crude JCO, diesel and ethanol in the presence of a surfactant. Three formulations of MFs with various composition of diesel and an ethanol-surfactant ratio were examined in terms of their biodiesel characteristics, performance and emission levels. For instance MF(E5), MF(E5)-LS1 and MF(E10)-LS1 were MFs without surfactant, ME with 5% and 10% of the ethanol-surfactant component, respectively. The high heating value, kinematic viscosity and water content of the MFs were close to the biodiesel standard and compatible for use with diesel engines. In addition, the MF(E5), gave an engine power, brake specific fuel consumption and exhaust gas temperature similar to those of petroleum-derived diesel. The emissions from these MFs showed a lower smoke emission than that of diesel, while the CO and CO_2 emissions were similar to those of diesel. Thus MF(E5) showed great potential for use as biofuel with less exhaust smoke emission in diesel engines without modification.

Introduction

Among various types of alternative fuels, biofuels is one of increasing interest to help assure future energy security as well as to reduce greenhouse gas emissions. At present, besides energy produced from municipal waste, another alternative energy is biofuel produced from vegetable oil due to its availability in large volumes [1]. The main source for biofuel production into automotive fuel is by the conversion of edible oil (e.g. soybean oil, canola oil and palm oil) into biodiesel. However, the large-scale production of biodiesel from edible oils may bring a global imbalance in food production resulting in the destruction of ecosystems and economic and social hardship [2]. *Jatropha curcas* seeds generally contain 30–40% oil by weight, and in almost all cultivars are non-edible (poisonous) due to the presence of the toxalbumen jatrophin [3,4]. Moreover, the tree can grow in poor or arid non-arable land. Therefore, *Jatropha curcas* oil (JCO) is drawn attention from researchers to be used as alternative fuel source since it does not compete with food or feed crops.

The methods that can modify the appropriate vegetable oil's characteristics to be better matched with diesel engines include pyrolysis, transesterification and microemulsion blending [5–7]. In general, transesterification is used to convert vegetable oil to

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 https://doi.org/10.1016/j.ref.2017.12.001

biodiesel (as fatty acid alcohol esters), which is a renewable, non-toxic biodegradation process [8]. However, transesterification produces unpurified by-products (i.e. glycerol, alcohol, catalyst, tri-, di- and mono-glycerides) and a large volume of contaminated wastewater [9]. Therefore, the sustainability of biofuel production as an alternative to fossil fuel sources has been challenged.

Microemulsion fuels (MFs) have been proposed and evaluated as an alternative method to produce fuels with suitable properties and avoid the problems of waste disposal because it is a simple technique with a low energy consumption and yields 100% product [10–12]. This technique needs a surfactants as an emulsifier to inhibit phase separation among three composition; diesel, JCO, and ethanol. Nonionic surfactants have previously been proposed to be used as emulsifiers in order to stabilize the miscibility of the JCO-ethanol-diesel emulsion [13,14] with the droplet size in microemulsion range [14]. A few studies consider MFs as microemulsion Winsor type II (water in oil phase) and some consider as Winsor type IV (continuous phase or single phase) [14–18]. To obtain microemulsion, selection of a surfactant is crucial factor. In our previous work, the results show that a fatty alcohol with one mole of ethylene oxide (EO) or Dehydol LS1 provides homogenous mixture with less viscosity than those with the others surfactants of the same fatty alcohol chain but higher in EO mole in their structure [13,14]. Some techniques such as dynamic light scattering and small-angle neutron scattering have been introduced for examination of microemulsion study in biofuel [19]. However, microemulsion structure of MFS is not included in this present study. Our Previous work reveals that the properties of MFs at a JCO: diesel: ethanol/surfactant (E/S) ratio of 20:75:5 and 20:70:10, where the E/S ratio was at 3/1, meet the biodiesel standard for the kinematic viscosity and water content but not for the acid number and flashpoint [13]. Nonetheless, the MFs formed at these two ratios have the potential to be used as biofuel in diesel engines without modification. Therefore, these 2 formulation ratio of MFs were selected for this present study on engine's performance and exhaust emission examination.

This study focused on investigating the conditions of MF formation to ensure that the MF was suitable for use with current diesel engines. Additionally, the efficiency of MFs on the diesel engine's performance and exhaust emission compared with commercial diesel was evaluated. The performance test consisted of measuring the engine power, brake specific fuel consumption (BSFC) and exhaust temperature. The combustion emission was measured in terms of carbon monoxide (CO), carbon dioxide (CO_2) and black smoke levels.

Materials and methods

Materials

Fatty alcohol ($C_{12–14}$) ethylene oxide (Dehydol LS1) of an approximate 99.9% active strength, used as a single nonionic surfactant, was supplied by Thai Ethoxylate Company Limited. The crude JCO used in this study was supplied by Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom, Thailand (WGS84: 14.03403, 99.97032). The commercial diesel fuel (D) was purchased from PTT Public Company Limited. Absolute ethanol (E) of 99.9% purity was purchased from RCI Labscan Limited.

Methods

Preparation of MFs

The crude JCO was clarified by centrifugation at 2750 × *g* for 10 min, and the supernatant (oil) was kept at 25 °C without being exposed to light and air. Ethanol and the Dehydol LSI surfactant were mixed at a 3:1 (v/v) ratio prior to blend with D and JCO at the appropriate ratios (see below), after which they were stored at 25 °C to allow the MF to reach equilibrium. The ethanol and surfactant ratio was selected from our previous work [13] as mentioned earlier. The MFs were prepared on a volumetric basis consisting of JCO, D and either E or E/S for the MF without and with surfactant, respectively. The MFs which were previously found to be transparent, clear and homogenous [13,14] were selected in this study, and were formulated as follows:

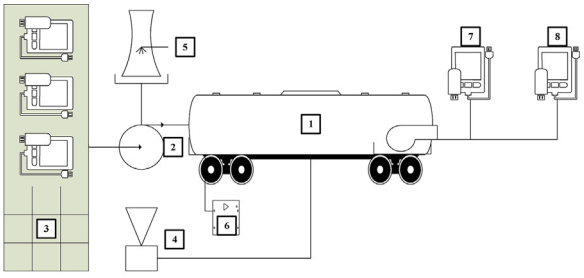
MF(E5) at a 20:75:5 (v/v) ratio of JCO:D:E (surfactant-free MF).
MF(E5)-LS1 at a 20:75:5 (v/v) ratio of JCO:D:E/S (E/S (v/v) ratio of 3:1) (Considered as a low surfactant concentration MF).
MF(E10)-LS1 at a 20:70:10 of JCO:D:E/S ratio of JCO:D:E/S (E/S (v/v) ratio of 3:1) (considered as a high surfactant concentration MF).

Characteristics of the MF fuel test

The high heating value (HHV), kinematic viscosity and water content were analyzed by an AC-350 automatic calorimeter following ASTM D240, a D445-E20L kinematic viscometer following ASTM D445and a Karl Fischer coulometer following ASTM D6304, respectively.

Performance and emission of MFs in a diesel engine test

The MFs were tested for their performance and emission levels compared with that of diesel in a two-cylinder-diesel engine. The engine was a four stroke, indirect injection, water cooled, 570 cc-displacement, and naturally aspirated air charge. The experimental set up, shown in Figure 1, consisted of a hydraulic dynamometer and controller to determine the engine torque and power. The fuel consumption rate of the engine was determined with an electronic weighting scale, having a readability of 0.1 g, and an electronic chronometer, having a sensitivity of 0.1 s. For analysis of the emissions, the CO and CO_2 levels were measured using a HORIBA gas analyzer and smoke emissions was measure using a Diesel Smoke meter.



1. Two-cylinder diesel engine	5. fuel consumption measurement
2. Hydraulic dynamometer	6. Tachometer
3. Dynamometer's controller	7. Gas emission detector
4. Cooling tower	8. Smoke meter

FIGURE 1
Schematic outline of the experimental setup.