Journal of Cleaner Production 65 (2014) 295–303

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Production of palm and jatropha based biodiesel and investigation of palm-jatropha combined blend properties, performance, exhaust emission and noise in an unmodified diesel engine

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A R T I C L E I N F O

Article history:
Received 19 April 2013
Received in revised form
20 September 2013
Accepted 21 September 2013
Available online 3 October 2013

Keywords:
Biodiesel
Palm-jatropha combined blend
Characterization
Engine performance
Emission analysis
Noise

A B S T R A C T

An ever increasing drift of energy consumption, unequal geographical distribution of natural wealth and the quest for low carbon fuel for a cleaner environment are sparking off the production and use of biodiesels in many countries around the globe. In this work, palm biodiesel and jatropha biodiesel were produced from the respective crude vegetable oils through transesterification, and the different physicochemical properties of the produced biodiesels have been presented, and found to be acceptable according to the ASTM standard of biodiesel specification. This paper presents experimental results of the research carried out to evaluate the BSFC, engine power, exhaust and noise emission characteristics of a combined palm and jatropha blend in a single-cylinder diesel engine at different engine speeds ranging from 1400 to 2200 rpm. Though the PBJB5 and PBJB10 biodiesels showed a slightly higher BSFC than diesel fuel, all the measured emission parameters and noise emission were significantly reduced, except for NO emission. CO emissions for PBJB5 and PBJB10 were 9.53% and 20.49% lower than for diesel fuel. By contrast, HC emissions for PBJB5 and PBJB10 were 3.69% and 7.81% lower than for diesel fuel. The sound levels produced by PBJB5 and PBJB10 were also reduced by 2.5% and 5% compared with diesel fuel due to their lubricity and damping characteristics.

1. Introduction

Modern civilization and transport systems are very dependent on fossil fuels which are non-renewable in nature. The rapidly growing demand for transport fuel and industrialization has caused serious threats to the environment and energy security of the world (Hussan et al., 2013). Global fossil fuel consumption increased by around 40% in 2011 compared with 2010 (British Petroleum, 2011). Moreover, only half of the usual energy demand can be supplied until 2023 with the current liquid fuel reserve (Owen et al., 2010). This enormous drift of fossil fuel consumption is seriously affecting our environment. These environmental degradation effects include global warming, air quality deterioration, ozone depletion, eutrophication, photochemical smog, oil spills, and acid rain (Abedin et al., 2013; Rizwanul Fattah et al., 2013). Among all automotive vehicles, diesel-operated vehicles are most popular due to their fuel efficiency and low emission of CO, HC and CO_2 (Kurani and Sperling, 1988). But it has been experimentally demonstrated that many human health hazards are associated with exposure to diesel exhaust emissions (Kagawa, 2002; Mills et al., 2007). Moreover, noise produced by road and rail traffic adversely affects human health. Around 20% of the population of the European Union suffers from unacceptable noise levels (Nijland and van Wee, 2008; Oltean-Dumbrava et al., 2013). Therefore, research must be carried out in order to reduce the noise level of diesel engines.

Biofuel has so far been backed by government policies in many countries due to its greater energy security, reduced environmental pollution, sustainability and other socio-economic issues (Pereira et al., 2012; Sanjid et al., 2013). The projection by Stuart Staniford back in 2008 on primary energy production from 1970 to 2050 strongly supports the increasing trend of renewable energy consumption (Staniford, 2008). The sustainability of biofuels is progressively promoting its acceptance and market demand will rise in the near future. Around 27% of transport fuel will be completely replaced by biofuels by 2050 according to the International Energy Agency IEA (2011). Though crude vegetable oils are incompatible with engines due to their high viscosity and low volatility, transesterified vegetable oils blended with diesel at up to 20% of total volume can certainly be considered in view of energy, environmental and economic concerns (Atabani et al., 2012).

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http://dx.doi.org/10.1016/j.jclepro.2013.09.026

Nomenclature

% vol	Percentages of volume
ASTM	American society for testing and materials
BSFC	Brake specific fuel consumption
BTE	Brake Thermal Efficiency
CN	Cetane Number
CO	Carbon-monoxide
CPO	Crude Palm Oil
EGT	Exhaust Gas Temperature
FAC	Fatty Acid Composition
FFA	Free Fatty Acid
GC	Gas Chromatography
HC	Hydrocarbon
H_2SO_4	Sulphuric Acid
IV	Iodine Value
KOH	Potassium Hydroxide
NO	Nitric oxide
NO_x	Oxides of nitrogen
ppm	Parts per million
rpm	Revolution per minute
SN	Saponification Number

Transesterification is the chemical reaction which yields biodiesel and glycerol from crude vegetable oil. Biodiesels and their blends with diesel fuel have similar properties to diesel fuel and meet the standard specification of the ASTM and EN test methods (Atabani et al., 2013). Apart from increasing NO_x emission, most biodiesels reduce different pollutant emissions (Rahman et al., 2013a). Moreover, all the carbons released by the combustion of biofuel are fixed by the plant through the process of photosynthesis. This is the concept of "carbon neutral fuel", emphasized by the Kyoto Protocol, which establishes the contribution of using biofuel in the prevention of global warming (Jayed et al., 2011). Though the utilisation of edible biodiesel feedstock has been criticized by some environmentalists, with a proper management system and an efficient supply chain, the use of biodiesel can reduce greenhouse gas emission as well as securing the food supply (Ng et al., 2012).

Among all the conventional edible biodiesel feedstock, palm is one of the most productive and economically suitable as an alternative biodiesel source. Average oil yield from a palm tree is 3–4 times higher than any other conventional biodiesel feedstock like rapeseed or sunflower. Besides, palm oil production needs less N-fertilizers and the energy needed in palm mills is provided by the combustion of palm fibres and shells, which reduces the carbon footprint (de Vries, 2008). According to the Malaysian Palm Oil Board, Malaysia is producing 19.4 million tons of crude palm oil every year (Tahir et al., 2013). Though palm oil is edible, this huge production of palm oil definitely permits the production of biodiesel from palm oil. Besides, using biodiesel based on waste frying palm oil in diesel engines will not affect the food supply (Canakci et al., 2009). By contrast, jatropha is a potential non-edible feedstock and the jatropha plant can be grown almost anywhere, even on gravel, sandy and saline soils. Its water requirement is extremely low. Hence, the use of jatropha seed oil is no threat to existing cultivable land and the food chain, unlike some other conventional edible feedstock. The plant itself can improve soil quality so that it can be used for other crops in the future. Extraction of biodiesel from jatropha seeds is simple and jatropha biodiesel exhibits more useful fuel properties than any other second-generation biodiesel feedstock. Jatropha oil is favoured over palm oil due to its cold filter plugging point (CFPP) value, which makes it a better option for use in cold climates (Kalam et al., 2012).

In recent years, studies have been carried out by several researchers on the performance and emission of palm biodiesel. Ndayishimiye and Tazerout (2011) investigated the performance and emission of a single-cylinder DI diesel engine fuelled with CPO blends, preheated palm oil and palm biodiesel–diesel blends. They found slightly higher BSFC for all the tested biofuels compared with diesel fuel. Engine BTE was slightly increased for CPO blends but decreased for all the other fuels tested. HC and CO emissions were reduced significantly (30–65%) for palm biodiesel compared with all the other fuels tested, though NO_x emission increased. Song et al. (2012) used pure palm biodiesel and 20% palm biodiesel blend to evaluate NO_x emission and soot formation in a 4-cylinder medium duty diesel engine. On average, the biodiesel emitted a higher level of NO_x than diesel fuel, though NO_x formation exhibited some inconsistency across all the fuels tested, while smoke concentration was consistently lower for palm biodiesel. Yusaf et al. (2011) investigated the performance and emission of a 4-cylinder Perkins diesel engine fueled with 25%, 50% and 75% CPO blends. At higher engine speed, they found lower BSFC and higher torque for the CPO blends, but the brake power produced was slightly lower. Oxygen and NO_x emissions were reduced, while CO and EGT were increased for CPO blends compared with diesel fuel.

Mofijur et al. (2013) experimented with a 4-stroke, DI single-cylinder diesel engine fueled with 10% and 20% jatropha biodiesel and measured the engine performance and emission. Higher BSFC, lower torque and lower brake power were found for jatropha biodiesels compared with diesel fuel. HC was reduced by up to 10% and CO was reduced by up to 25% for jatropha biodiesel, while NO_x emission increased by up to 6%. Chauhan et al. (2012) investigated the performance and emission of 5%, 10%, 20%, 30% and 100% jatropha biodiesel blends in a single-cylinder, DI diesel engine. They found that engine performance for jatropha biodiesel was comparable with the diesel fuel. Smoke, HC and CO emissions were reduced, but increased NO_x emissions were found over the whole range of experiments. Sahoo and Das (2009) compared the combustion characteristics of jatropha, polanga and karanja based biodiesel in a 4-stroke, single-cylinder diesel engine. They reported a shorter ignition delay period for pure jatropha biodiesel compared with diesel fuel and karanja biodiesel. However, regarding peak cylinder pressure, polanga biodiesel was superior to jatropha and karanja biodiesels. Sahoo et al. (2009) carried out research on the same feedstock in a 3-cylinder, AVL make CI engine to evaluate the engine performance and emission characteristics. They reported a slight reduction in power and increase in BSFC for all the biodiesels tested compared with diesel fuel. However, the maximum increase in power was observed for the 50% blend of jatropha biodiesel and the maximum BSFC reduction was observed for the 20% blend of jatropha biodiesel. Significant reductions of HC, smoke and particulate matter emission were observed for all the biodiesels tested compared with the diesel fuel. However, their CO and NO_x emissions increased slightly.

Experimental investigations on engine performance, emission and noise for a combined palm and jatropha blend were not found in scientific indexes. This experimental endeavour deals with the possibility of using combined palm and jatropha biodiesel blends for energy generation in order to reduce air and noise pollution. The steps in the transesterification undertaken to obtain biodiesel from crude vegetable oil, as well as the characterisation of the produced biodiesel are described. Performance and emission results for combined palm and jatropha biodiesel blends in a single-cylinder diesel engine are also represented graphically and compared with diesel fuel, palm biodiesel blend and jatropha biodiesel blend.

2. Materials and methodology

This research work was carried out with the aim of analysing the performance and emissions of a single-cylinder diesel engine using