



Evaluating the potential of biodiesel (via recycled cooking oil) use in Singapore, an urban city



Sze-Hwee Ho*, Yiik-Diew Wong, Victor Wei-Chung Chang

Centre for Infrastructure Systems, School of Civil and Environmental Engineering, Nanyang Technological University, 50 Nanyang Avenue Singapore 639798, Singapore

ARTICLE INFO

Article history:

Received 28 February 2014
Received in revised form 6 August 2014
Accepted 7 August 2014
Available online 1 September 2014

Keywords:

Biodiesel
Mitigation measure
Recycled cooking oil (RCO)

ABSTRACT

Singapore has pledged to attain 7–11% Business-As-Usual carbon emissions reduction by 2020. About 19% of CO₂ contribution stemmed from road transport in 2005. Commercial vehicles, which use mainly diesel, consumed 695 million litres diesel in 2012. An estimated 115,585 tonnes or 127 million litres cooking oils (derived from seeds/fruits) were consumed in 2010, in which the bulk of used cooking oil is re-incorporated into the food preparation process while only a small amount is being recycled into biodiesel or disposed into the sewerage. Nevertheless, the present research reveals that biodiesel derived from spent cooking oil has potential to be a viable fuel supplement. Surveys were carried out involving three market segments – suppliers, processors and end-users – to identify the barriers and obstacles in mass production of biodiesel. A key enabler of biodiesel as a fuel supplement towards a greener environment lies in government mandate/policies in promoting greater biodiesel usage.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Singapore is committed to mitigate change and has pledged unconditionally to achieve 7–11% below Business-As-Usual (BAU) carbon emissions reduction by 2020 (Singapore's National Statement, 2011). Road transport has been identified as a key climate change sector, which has provided basis of this research into biodiesel production from recycled cooking oil (RCO) as fuel supplement.

1.1. Road transport is a major consumer of energy

Globally, annual consumption of energy is on an uptrend, especially for emerging economies such as China and India. The most feasible way to cope with this growing demand of scarce petroleum reserves is by supplementing with alternative fuels (renewable energy resources), in particular, biodiesel (Sheehan et al., 1998; Fernando et al., 2006). A growing energy sector is that of transport, particularly road transport. In 2009, EU-27 consumed 1703 million tonnes of oil equivalent (mtoe) whereby one third was taken up by the transport sector (European Commission-Eurostat, 2011). In 2007 (EU-27), road transport sector (excluding rail transport and

pipelines) emitted 920.4 million tonnes CO₂ equivalent of greenhouse gases emissions (European Commission, 2010). In 2009, the transport sector in the United States (U.S.) consumed 27,600 trillion BTU (approximately 696 mtoe), whereby 82.5% was accounted by road transport (exclude rail) (US Department of Energy-Energy Efficiency & Renewable Energy, 2009). In 2005, Singapore's road transport energy consumption (excluding aviation/maritime transport) was estimated at 17% (approximately 7056 kilo tonnes), being ranked behind power generation (48%) and industry (33%). Clearly, road transport is a major energy consumption sector, and likewise a large contributor of greenhouse gases (GHGs).

2. Literature review

2.1. What is biodiesel/bio-fuel?

Bio-fuel production can be broadly classified into three types based on the material inputs. The first type is derived from food crops such as seeds, grains and sugar crops whereby land-use efficiency is low. The second type is made from the non-food crops and biomass wastes (lignocellulosic biomass) with relatively higher land-use efficiency while the third type, as being researched, involves using algae as the feedstock with high yields and low resource utilisation. As alternative to fossil diesel, biodiesel, by definition, is a fuel comprising mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. Biodiesel, having

* Corresponding author. Tel.: +65 90185746; fax: +65 67910676.
E-mail addresses: ho005ee@e.ntu.edu.sg, szehwee_ho@hotmail.com (S.-H. Ho).

met the requirements of ASTM D 6751, has been used to power unmodified diesel engines in the United States. Blends of 5–30% biodiesel with fossil diesel do not require engine modifications. In Europe, similar standards are in place as accorded in EN14214 which applies to biodiesel produced from vegetable oils or animal fats with methanol, the end-products being referred as fatty acid methyl esters (FAME).

Biodiesel, being renewable and environmental-friendly, is the best candidate for diesel fuels in diesel engines (Demirbas, 2007). Renewable sources include *Jatropha mahafalensis* oil, sunflower oil, palm oil, soybean oil and canola oil (Dyer et al., 2010; Kochaphum et al., 2013; Sonnleitner et al., 2013). It is the only alternative transport fuel that at a low blend with diesel can be used without much modification to the engines of operational vehicles (Math et al., 2010). The risks of handling, transportation and storage for biodiesel are also much lower as compared to fossil fuels. Having no aromatic compounds and sulphur content, resulting harmful emissions are also reduced. Moreover, the oxygen content of biodiesel results in better combustion which reduces soot and particulate matter emissions (Lapuerta et al., 2005, 2008). Demirbas (2010) noted that the main diesel alternatives are biodiesel, vegetable oil, Fischer–Tropch (FT) diesel and dimethyl ether (DME) whereby the last two types are derived from natural gas. Both biodiesel and fossil diesel have similar viscosity but biodiesel has the advantages of biodegradability, non-flammability, and non-explosiveness (Yusuf et al., 2011).

2.2. Advantages of biodiesel: cleaner emissions

Biodiesel exhaust emissions have been researched to some extent. A study involving biodiesel showed that combustion efficiency remained constant using either biodiesel produced from waste olive oil or conventional diesel. Results also showed that the use of biodiesel resulted in lower emissions of CO (36% on average), CO₂ (3% on average), NO (20% on average), and SO₂ (35% on average), with increase in emissions of NO₂ (45% on average) (Dorado et al., 2003). Higher oxygen level in biodiesel via processing recycled cooking oil (RCO) enables a leaner combustion and hence, reduced CO emissions. Other studies showed that biodiesel generated from RCO emitted higher NO_x and PM, but lower SO₂, than fossil diesel fuel (Wu et al., 2007; Palash et al., 2013). Another review suggested that the engine performance using RCO biodiesel and its blends was only marginally poorer compared to fossil diesel while NO_x emissions were slightly higher while un-burnt hydrocarbon emissions were lower (Enweremadu and Rutto, 2010). However, tests using 30% and 70% blends of biodiesel resulted in a sharp decrease in both smoke or soot and particulate matter emissions as biodiesel concentration was increased, average particle size was also reduced with biodiesel concentration, but no significant increase was found in the range of the smallest particles (Lapuerta et al., 2008; Ismail et al., 2013). Total hydrocarbons (THC) and CO were found to be reduced with biodiesel (Amini-Niaki and Ghazanfari, 2013; Roy et al., 2013). Other pollutants such as polycyclic aromatic hydrocarbons (PAH) also have been found to be significantly reduced with the use of biodiesel (Murugesan et al., 2009; Armas et al., 2013; Chauhan et al., 2013).

2.3. Why biodiesel from recycled cooking oil (RCO)?

There inherently exist many by-products suitable as feedstock for biodiesel. Waste cooking oil, as referring to spent cooking oil that is being scrapped, for biodiesel generation and application is the research focus in this study. Recycling waste cooking oil engenders benefits in three ways: usage of fossil diesel is reduced; waste disposal is minimised; and spent cooking oil is kept out from re-entering the human food chain. This research investigates recycled

cooking oil (RCO) as feedstock for biodiesel which can be used as road transport fuel, and its feasibility to be adopted and accepted in a city like Singapore.

RCO can be a viable and effective source of biodiesel for cities, as found in a study into recycling of waste palm cooking oil in Malaysia as the output's yield was not inferior to biodiesel produced from expensive vegetable oil (Tan et al., 2011). Kyoto, a Japanese city, had detailed results of powering the city buses with biodiesel from RCO (City of Kyoto Environmental Policy Bureau, 2009). RCO is one of the most promising alternatives in the production of biodiesel because not only it is the cheapest feedstock but it also avoids the expense of treating RCO as a waste residue (Avellaneda and Salvadó, 2011). The generation of energy from RCO is an effective technique for waste management, as well as a beneficial form of energy recovery (Singhabhandhu and Tezuka, 2010). Moreover, biodiesel generated from RCO is found to be of comparable quality to diesel (fossil origin) (Banerjee and Chakraborty, 2009). However, a major hurdle to mass-production of biodiesel is the cost as compared to conventional diesel fuel, especially if fresh cooking oil is used as the feedstock. On the other hand, RCO being a waste residue is an economic source for biodiesel production, especially for increasing the supply of raw materials for biodiesel production (Enweremadu and Mbarawa, 2009; Zhang et al., 2012). This is especially the case when feedstock costs constitute approximately 80% of the total costs of operation when using cooking oils (Balat and Balat, 2008).

2.4. Pre-treatment of RCO prior to transesterification

Pre-treatment processes are necessary prior to transesterification reactions, regardless for the types of catalyst used. These include predominantly removal of solids (such as food residue) and excessive water content. Removal of solids can be carried out via filtration and centrifuge (Issariyakul et al., 2007; Enweremadu and Mbarawa, 2009). In particular to alkali-catalysed transesterification, prior removal/reduction of water and free fatty acid (FFA) are important as both incurred saponification which depletes the alkaline catalyst (Canakci and Van Gerpen, 2003; Cvengroš and Cvengrošová, 2004). Water is usually removed by mixing with silica gel, heating, evaporation and drying. FFA removal involves formation of soaps with alkalis and subsequent removal (Cvengroš and Cvengrošová, 2004; Issariyakul et al., 2007).

2.5. Transesterification reactions

Transesterification reactions include (1) alkali catalyst; (2) acid catalyst; (3) alkali and acid catalyst (2-step); (4) enzyme catalyst; and (5) no catalyst conversion. Alkaline processes usually employ the use of sodium hydroxide (NaOH), potassium hydroxide (KOH) and sodium methoxide (CH₃ONa). However, high concentration of FFA and water are detrimental to the reaction as they deplete the catalyst with soap formation. It was found that high yield can be obtained with less than 1% of FFA (Canakci and Van Gerpen, 2003; Encinar et al., 2005; Helwani et al., 2009; Math et al., 2010). Acidic processes use strong acids such as hydrochloric acid (HCl) and sulphuric acid (H₂SO₄). Acid catalyst is insensitive to FFA content of more than 1%, unlike alkaline catalyst. However, main disadvantages include water formation in the mixture and lower reaction rates (longer process time) (Nye et al., 1983; Freedman et al., 1984; Marchetti et al., 2007). Two-step processes overcome the disadvantages of using only alkaline or acid catalyst, saponification and longer reaction time, respectively. The first step is typically carried out with the acidic catalyst to decrease FFA to less than 1% and transesterification is continued with the alkaline catalyst (Wang et al., 2007; Enweremadu and Mbarawa, 2009). The use of enzyme catalyst also overcomes the issues of high FFA concentration and water content. In addition, reaction can take place under normal

Download English Version:

<https://daneshyari.com/en/article/1062867>

Download Persian Version:

<https://daneshyari.com/article/1062867>

[Daneshyari.com](https://daneshyari.com)