A review on characteristics, advantages and limitations of palm oil biofuel

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Abstract: Consumption and use of natural resources is a high concerning issue in modern days. Increase in fuel price, limited resources of fossil oil and great concerns on environmental matters has led the researchers and scientists to concerted and escalating research and development efforts in search of renewable and environmental friendly alternative energy sources. In this connection, recent strong demand for renewable fuels has resulted in increased production of biofuels worldwide for solving transportation fuel problems. Currently, biofuels from palm oil is being established as a great source of alternative fuel. Palm oil can be used to produce biodiesel, which is also known as palm oil methyl ester. Palm oil biodiesel is often blended with other fuels to create palm oil biodiesel blends. This paper highlights on biofuel/biodiesel production from palm oil, use, advantages and limitations.

Keywords: palm oil; biofuel; biodiesel; emission; transesterification; green house gas; GHG; energy balance; crude palm oil; CPO; vegetable oil; palm kernel oil; PKO.


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1 Introduction

Palm oil produce from the fruit of the oil palm tree (*Elaeis guineensis* Jacq.) is the second most traded vegetable oil crop in the world, after soy (Casson, 2003). It is native to West Africa, where local populations have traditionally used it to make foodstuffs, medicines, woven material and wine. The palm is now planted in large-scale plantations throughout the tropics because it is used in a number of commercial products including cooking oil, soap, cosmetics and margarine (Hai, 2002). However, over 90% of the world’s palm oil exports are produced in Malaysia and Indonesia (Balch, 2013). Palm oil is still mostly used in the manufacture of food products and is found in one in ten products sold in the UK supermarkets (‘Friends of the Earth: the oil for ape scandal’, 2005). Palm oil is a very productive crop. The yield (amount of oil produced per hectare per year) is far greater than for other vegetable oils, while production costs are lower. This lower cost is mainly due to low labour costs in the countries in which palm oil is grown. The versatility has seen palm oil replace animal and other vegetable oils in a wide variety of products. Today, it is used as cooking oil, main ingredient for most margarine, in confectionary, ice cream and ready-to-eat meals, the base for most liquid detergents, soaps, and shampoos, the base for lipstick, waxes, and polishes, an industrial lubricant and a biofuel (http://wwf.panda.org/what_we_do/footprint/agriculture/palm_oil/about/).

Figure 1 represents information on palm oil collected from oil world, March 2014 database.

It is seen that, four major produced vegetable oils consumes 85% market share where palm oil has the maximum share of 35% (56,233,000 tons) and amount of palm oil produced per hectare per year is also maximum compared to other oils. In 2013, Indonesia and Malaysia produce 84% (47.6 MT) palm oil, where rest of the share produced by Thailand, Cambodia, Nigeria, Papua New Guinea, Ecuador and others. But in the case of consumption of palm oil, India is on the top among the other countries. About 21% (8.3 MT) palm oil consumed by India. Consumption by other countries is: Indonesia 20% (7.9 MT), EU 17% (6.6 MT), China 16% (6.2 MT), Malaysia 6% (2.3 MT), Pakistan 5% (2.1 MT), Nigeria 5% (1.8 MT), Thailand 4% (1.5 MT), the USA 3% (1.2 MT), and Bangladesh 3% (1.2 MT). Again, Figure 2 shows global supply and demand for palm oil with major trade flows. It is seen that, the USA, EU, India and China imports and consumes palm oil from Indonesia and Malaysia as this two nations produce and consume global palm oil at 86% and 21% capacity, respectively.
Figure 1. (a) Vegetable oil production in 2013 (b) Vegetable oil yield per hectare per year (c) Palm oil production in 2013 and (d) Top ten palm oil consuming nations in 2013 (see online version for colours)

4 major vegetable oils = 85% market share

Source: http://greenpalm.org/
Figure 1  (a) Vegetable oil production in 2013 (b) Vegetable oil yield per hectare per year (c) Palm oil production in 2013 and (d) Top ten palm oil consuming nations in 2013 (continued) (see online version for colours)

(c) Palm Oil Production 2013 - Tonnes

Indonesia & Malaysia = 84 % market share

(d) Top 10 Palm Oil Consuming Nations 2013 - Tonnes

Total palm oil consumption 57 million tonnes

Source: http://greenpalm.org/
Palm oil as biofuel

The price fluctuation for biodiesel in recent years has prompted biodiesel producers to search for more economical alternative raw materials for biodiesel production (Nang et al., 2009). However, palm oil is now starting to be used as an ingredient in bio-diesel and as a fuel to be burnt in power stations to produce electricity. This is a new market for palm oil which has the potential to dramatically increase global demand for this commodity (‘Friends of the Earth: the use of palm oil for biofuel and as biomass for energy’, 2006). Palm oil can be used to produce biodiesel, which is also known as palm oil methyl ester (POME) (Rojas, 2007). POME is created through a process called transesterification. Palm oil biodiesel is often blended with other fuels to create palm oil biodiesel blends (Sadrolhosseini et al., 2011). Palm oil biodiesel meets the European EN 14214 standard for biodiesels (Rojas, 2007). The world’s largest palm oil biodiesel plant is the Finnish operated Neste Oil biodiesel plant in Singapore, which opened in 2011 (Yahya, 2011). The organic waste matter that is produced when processing oil palm, including oil palm shells and oil palm fruit bunches can also be used to produce energy. This waste material can be converted into pellets that can be used as a biofuel (Choong, 2012). Additionally, palm oil that has been used to fry foods can be converted...
into methyl esters for biodiesel. The used cooking oil is chemically treated to create a biodiesel similar to petroleum diesel (Kheang et al., 2006).

Biodiesel made from palm oil grown on sustainable non-forest land and from established plantations effectively reduces greenhouse gas emissions (GHG) (Beer et al., 2007). According to Greenpeace (2007), clearing peat land to plant oil palms releases large amounts of greenhouse gasses, and that biodiesel produced from oil palms grown on this land may not result in a net reduction of GHG. However, research by Malaysia’s Tropical Peat Research Unit (MTPRU) has found that oil palm plantations developed on peat land produce lower carbon dioxide emissions than forest peat swamp. However, it has been suggested that this research unit was commissioned by politicians who have interests in the palm oil industry (Wong, 2010). In 2011, eight of Malaysia’s Federal Land Development Authority (FELDA) plantations were certified under the International Sustainability and Carbon Certification System (ISCC), becoming part of Asia’s first ISCC certified supply and production chain for palm biodiesel. This certification system complies with the European Union’s Renewable Energy Directive (RED) (Vogele, 2011). In 2012, the European Commission approved the Roundtable on Sustainable Palm Oil’s (RSPO, 2012) biofuel certification scheme allowing certified sustainable palm oil biofuel to be sold in Europe. According to Kittithammavong et al. (2014), Table 1 shows the energy outputs. Here, the energy outputs are calculated based on utilisation of palm kernel, fibre, empty fruit bunch, shell, pure methanol, pure glycerol and biodiesel.

Table 1   Energy outputs

<table>
<thead>
<tr>
<th>Material outputs</th>
<th>Quantity (kg/L)</th>
<th>Energy content (MJ/kg)</th>
<th>Energy output (MJ/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm kernel</td>
<td>1.02832</td>
<td>17</td>
<td>17.48</td>
</tr>
<tr>
<td>Fibre</td>
<td>2.03479</td>
<td>11.4</td>
<td>23.20</td>
</tr>
<tr>
<td>Shell</td>
<td>1.06809</td>
<td>18.46</td>
<td>19.72</td>
</tr>
<tr>
<td>EFB</td>
<td>4.14310</td>
<td>7.24</td>
<td>30.00</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>0.87000</td>
<td>38.07</td>
<td>33.12</td>
</tr>
<tr>
<td>Pure glycerol</td>
<td>0.04581</td>
<td>19</td>
<td>0.87</td>
</tr>
<tr>
<td>Pure methanol</td>
<td>0.09127</td>
<td>20.094</td>
<td>1.83</td>
</tr>
</tbody>
</table>

Source: Kittithammavong et al. (2014)

3 Production of palm biodiesel

Palm biodiesel is obtained by transesterification (alcoholysis) of palm oil. Figure 3 shows the flowchart of the esterification process. Esterification may be carried out batch wise at 200°C to 250°C under pressure. For high yield, the water produced during the reaction has to be removed continuously. Esterification can also be carried out continuously in a counter current reaction column using superheated methanol (Kreutzer, 1984). Esterification is the preferred method for ester preparation from palm oil and fat fractions such as palm stearin and olein. The process is the chemical reaction between triglycerides and alcohol in the presence of alkaline liquid catalyst, usually sodium or potassium methoxide to produce fatty acid monoesters. The long and branched chain triglyceride molecules are transformed into monoesters and glycerin as schematically represented in Figure 4 (Abdullah et al., 2007). Practically and chemically, all vegetable oils can be used
to produce biodiesel. Further considerations towards its use could be directly related to the local availability, their other uses, productivity and sometimes socioeconomic influences. Vegetable oils such as crude palm oil (CPO) with varying amounts of free fatty acids can be converted to esters in a continuous process by combining the esterification and transesterification processes (May et al., 2005).

**Figure 3** Flowchart of the esterification process

![Flowchart of the esterification process](source)

Source: Beer et al. (2007)

**Figure 4** General representation of the catalytic transesterification process of triglycerides with methanol to produce biodiesel

![General representation of the catalytic transesterification process](source)

Source: Abdullah et al. (2007)

A schematic diagram for the process flow of palm oil biodiesel production technology is shown in Figure 5, which is mostly originated from Malaysian Palm Oil Board (MPBO). MPOB (2008) claims that this technology can achieve a minimum overall biodiesel yield of 98% after optimisation and the biodiesel products meet the full specifications of EN 14214 and ASTM D 6751. The technology is also very economical as only low pressure and temperature are required and the commissioning time is considerably short. Under normal conditions, full specification standards can be achieved in less than 24 hours after
feeding of refined bleached and deodorised palm oil/olein (RBDPO) (Lim and Lee, 2010). The technology has been licensed to two companies who will build and sell biodiesel plants based on MPOB technology. In 2008, these licensees have sold a total of ten plants within and outside Malaysia.

Figure 5  Schematic diagram for palm biodiesel processing by MPOB

Source: MPOB (2008)

4 Palm biodiesel properties, performance and emission characteristics

4.1 Properties of palm biodiesel

The biodiesel standard testing materials are American standards ASTM D6751 and European Union standard EN 14214 for biodiesel fuel (Atadashi et al., 2010). In general terms, biodiesel may be defined as a domestic renewable fuel for diesel engines derived from natural oil like palm, soybean and rapeseed oil that meet the specifications of ASTM D6751 or EN 14214 (Ong et al., 2011). Table 2 shows fuel properties of normal and low pour point palm biodiesel from MPBO (http://www.palmoilworld.org/biodiesel.html). The quality of biodiesel fuel can be significantly influenced by numerous factors among others include: the quality of feedstock, fatty acid composition of the vegetable oil, animal fats and waste oil, and type of production.
Table 2

<table>
<thead>
<tr>
<th>Properties</th>
<th>Unit</th>
<th>Normal palm biodiesel</th>
<th>Low pour point palm biodiesel</th>
<th>EN 14214/2003</th>
<th>ASTM D6751-07b</th>
<th>MS 2008:2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ester content</td>
<td>% (m m^-1)</td>
<td>98.5</td>
<td>98.0–99.5</td>
<td>96.5 (min.)</td>
<td>-</td>
<td>96.5 (min.)</td>
</tr>
<tr>
<td>Density at 15°C</td>
<td>kg m^{-3}</td>
<td>878.3</td>
<td>870–890</td>
<td>860–900</td>
<td>-</td>
<td>860–900</td>
</tr>
<tr>
<td>Viscosity at 15°C</td>
<td>mm^2 s^{-1}</td>
<td>4.415</td>
<td>4.423</td>
<td>3.50–5.00</td>
<td>1.9–6.0</td>
<td>3.50–5.00</td>
</tr>
<tr>
<td>Flash point</td>
<td>°C</td>
<td>182</td>
<td>130</td>
<td>120 (min.)</td>
<td>130 (min.)</td>
<td>120 (min.)</td>
</tr>
<tr>
<td>Cloud point</td>
<td>°C</td>
<td>15</td>
<td>–18–0</td>
<td>-</td>
<td>Report</td>
<td>-</td>
</tr>
<tr>
<td>Pour point</td>
<td>°C</td>
<td>15</td>
<td>–21–0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cold filter plugging point</td>
<td>°C</td>
<td>15</td>
<td>–18–0</td>
<td>-</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>Sulphur content</td>
<td>mg kg^{-1}</td>
<td>&lt; 10</td>
<td>10 (max.)</td>
<td>15 (max.) Grade S15 500</td>
<td>10 (max.)</td>
<td></td>
</tr>
<tr>
<td>Carbon residue (on 10% distillation residue)</td>
<td>% (m m^-1)</td>
<td>0.02</td>
<td>0.03</td>
<td>0.30 (max.) 0.050 (max.) (100% sample)</td>
<td>0.30 (max.) (10% distillation residue) 0.050 (max.) (100% sample)</td>
<td></td>
</tr>
<tr>
<td>Acid value</td>
<td>mg KOH g^{-1}</td>
<td>&lt; 0.5</td>
<td>&lt; 0.5</td>
<td>0.50 (max.) 0.50 (max.)</td>
<td>0.50 (max.)</td>
<td></td>
</tr>
<tr>
<td>Sulphated ash content</td>
<td>% (m m^-1)</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.02 (max.) 0.02 (max.)</td>
<td>0.02 (max.)</td>
<td></td>
</tr>
<tr>
<td>Water content</td>
<td>mg kg^{-1}</td>
<td>&lt; 500</td>
<td>500</td>
<td>500 (max.) 500 (max.)</td>
<td>500 (max.)</td>
<td></td>
</tr>
<tr>
<td>Total contamination</td>
<td>mg kg^{-1}</td>
<td>12</td>
<td>14</td>
<td>24 (max.) - 24 (max.)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cetane number</td>
<td>Rating</td>
<td>la</td>
<td>la</td>
<td>Class 1 No. 3 (max.)</td>
<td>Class 1</td>
<td></td>
</tr>
<tr>
<td>Copper strip corrosion (3 hr at 50°C)</td>
<td>Rating</td>
<td>la</td>
<td>la</td>
<td>110 (max.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidation stability, 110°C</td>
<td>hr</td>
<td>16</td>
<td>10.2</td>
<td>6 (min.) 3 (min.)</td>
<td>6 (min.)</td>
<td></td>
</tr>
<tr>
<td>Iodine value</td>
<td>g iodine/100 g</td>
<td>52</td>
<td>&lt; 100</td>
<td>120 (max.) - 110 (max.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linolenic acid methyl ester</td>
<td>% (m m^-1)</td>
<td>&lt; 0.5</td>
<td>&lt; 0.5</td>
<td>12 (max.) - 12 (max.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyunsaturated methyl esters (≥ 4 double bonds)</td>
<td>% (m m^-1)</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>1 (max.) - 1 (max.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol content</td>
<td>% (m m^-1)</td>
<td>&lt; 0.2</td>
<td>&lt; 0.2</td>
<td>0.2 (max.) 0.2 (max.)</td>
<td>0.2 (max.)</td>
<td></td>
</tr>
<tr>
<td>Monoglyceride content</td>
<td>% (m m^-1)</td>
<td>&lt; 0.8</td>
<td>&lt; 0.8</td>
<td>0.8 (max.) - 0.8 (max.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diglyceride content</td>
<td>% (m m^-1)</td>
<td>&lt; 0.2</td>
<td>&lt; 0.2</td>
<td>0.2 (max.) - 0.2 (max.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triglyceride content</td>
<td>% (m m^-1)</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>0.1 (max.) - 0.1 (max.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free glycerol</td>
<td>% (m m^-1)</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.02 (max.) 0.02 (max.)</td>
<td>0.02 (max.)</td>
<td></td>
</tr>
<tr>
<td>Total glycerol</td>
<td>% (m m^-1)</td>
<td>&lt; 0.20</td>
<td>&lt; 0.20</td>
<td>0.25 (max.) 0.24 (max.)</td>
<td>0.25 (max.)</td>
<td></td>
</tr>
<tr>
<td>Phosphorus content</td>
<td>mg kg^{-1}</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>10.0 (max.) 10.0 (max.)</td>
<td>10.0 (max.)</td>
<td></td>
</tr>
<tr>
<td>Group-I metals (Na+K)</td>
<td>mg kg^{-1}</td>
<td>3.1</td>
<td>3.1</td>
<td>5.0 (max.) 5.0 (max.)</td>
<td>5.0 (max.)</td>
<td></td>
</tr>
<tr>
<td>Group-II metals (Ca+Mg)</td>
<td>mg kg^{-1}</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>5.0 (max.) 5.0 (max.)</td>
<td>5.0 (max.)</td>
<td></td>
</tr>
<tr>
<td>Distillation temperature, 90% recovered (T90)</td>
<td>°C</td>
<td>&lt; 360</td>
<td>&lt; 360</td>
<td>360 (max.) - 360 (max.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2 Performance of palm biodiesel

The findings and outputs for performance of palm biodiesel fuel in diesel engine are reviewed here. The performance parameter such as brake thermal efficiency, specific fuel consumption and power output for palm oil are discussed below (Ong et al., 2010). Performance, emissions and heat losses of palm biodiesel blends in a diesel engine is investigated by Abedin et al. (2014). They have shown that after the successful implementation of B5, 5% palm-based biodiesel in Malaysia; replacing it with B10, 10% or even a higher blending ratio. The experiment was conducted in a four-cylinder diesel engine fuelled with B5, 10%, and 20% blends of palm (PB10 and PB20) and compared with fossil diesel at full load and in the speed range of 1,000 to 4,000 RPM. The brake power (BP) was decreased on average 2.3% to 10.7% while operating on 10% blends of palm biodiesel. An average of 26.4% brake specific fuel consumption (BSFC) increment was observed for PB20 blends. An average of 30.7% carbon monoxide (CO) and 25.8% hydrocarbon (HC) emission reductions were found for 20% blends. Moreover, on average, the nitrogen oxides (NOx) emission is decreased by 3.3% while operating on PB10 and PB20 blends. Again, an effect of antioxidant on the performance and emission characteristics of a diesel engine fuelled with palm biodiesel blends is examined by Fattah et al. (2014). An experimental investigation of the effect of antioxidant addition to palm biodiesel on engine performance and emission characteristics is carried out. A 42 kW, 1.8 L, four-cylinder diesel engine was used to carry out the tests under conditions of constant load and varying speed. The results showed that, B20 and antioxidant-treated B20 produced 0.68~1.02% lower BP and 4.03~4.71% higher BSFC compared to diesel. Both of the antioxidants reduced NOx by a mean of 9.8~12.6% compared to B20. However, compared to B20, mean increases in CO and HC emissions of 8.6~12.3% and 9.1~12.0%, respectively were observed. The emission levels of the three pollutants were lower than those of diesel. A study of combustion performance and exhaust emissions from the non-pressurised combustion of palm oil biodiesel blends were performed by Ng and Gan (2010). Here, levels of exhaust species from the combustion of POME and its blends with no. 2 diesel in a non-pressurised, water-cooled combustion chamber are evaluated. The study explores the correlations between emission species and fuel pumping pressures over a range of equivalence ratios (ERs). The work indicated the potential use of palm oil biodiesels in small-scale liquid fuel burners. The experimental study shows that, optimum combustion in non-pressurised burner system occurs over a narrow band of ER ranging from 0.75 to 0.85. The combustion quality was offset by the accompanying increase in NO level when the POME content is raised. Lin et al. (2006) investigated on polycyclic aromatic hydrocarbons (PAHs) emissions and energy efficiency of palm biodiesel blends fuelled on diesel generator. The results showed that BSFC increased with rising palm biodiesel blends due to the low gross heat value of palm biodiesel. Sapuan et al. (1996) highlight that power output was almost same for neat palm oil blend of palm oil diesel fuel and pure diesel fuel. Short-term using of palm oil fuel showed no adverse effects. Another experimental analysis was carried out by Ndayishimiye and Tazerout (2011) with palm oil-based biofuel using in the internal combustion engines to measure the performance and emissions characteristics. Here, the experiments were initially carried out with diesel oil for providing baseline data. The results show that, a high fraction of palm oil in diesel fuel decreases the heating value of the blend. The brake thermal efficiency increases for the palm oil/diesel blends. HC emissions for all those fuels except for the oil/diesel blends are found lower, while CO
emissions rise for all types of fuels. NO\textsubscript{x} emissions are higher at low load, but lower at full load, for the engine fuelled with palm oil and lower both at middle and full load for the engine fuelled with the esters.

**Figure 6** Emissions from various biofuels (CO\textsubscript{2}/mj) (see online version for colours)

![Default value (CO2/mj) of various fuels according to EU data](source)

Source: Mongabay.com (2012)

### 4.3 Emissions of palm biodiesel

Biodiesel mainly emits carbon monoxide, carbon dioxide, nitrogen oxides, sulphur oxides and smoke (Ong et al., 2011). According to the European Commission, GHG from palm oil-based biodiesel are the highest among major biofuels when the effects of deforestation and peat lands degradation are considered. Emissions estimates depend heavily on assumptions on how biofuels are produced. Palm oil producers who have established plantations without converting rainforest or draining carbon-rich peat lands are bound to have lower emissions than those who destroyed forest. The palm oil industry has
traditionally opposed any effort to include indirect land use change in emissions estimates, arguing that environmental concerns over palm oil production is merely thinly veiled protectionism. Environmentalists and carbon scientists however usually disagree, arguing that conversion of forests and peat lands is a major source of GHG (Mongabay.com, 2012). Figure 6 shows the emission of carbon dioxide (CO₂) equivalent per mega joule according to the EU data for various biofuels.

A study on energy balances and GHG of palm oil biodiesel in Indonesia carried out by Harsono et al. (2012). The study presents a cradle-to-gate assessment of the energy balances and GHG emissions of Indonesian palm oil biodiesel production. The largest GHG emissions result from land-use change (LUC) effects, followed by the transesterification, fertiliser production, agricultural production processes, milling, and transportation. Pehnelt and Vietze (2013) calculated GHG emissions saving of palm oil biodiesel. Their aim was to calculate realistic and transparent scenario-based CO₂ emission values for the GHG emissions savings of palm oil fuel compared with fossil fuel. Using the calculation scheme proposed by the RED, they derived a more realistic overall GHG emissions saving value for palm oil diesel by using current input and output data of biofuel production in South-East Asia. Their results indicate values for the GHG emissions savings potential of palm oil biodiesel not only above the 19% default and 36% typical value published in RED but also above the 35% sustainable threshold. Moreover, their findings conclude the more accurate GHG emissions saving value for palm oil feedstock for electricity generation to be 52%, and for transportation biodiesel between 38.5% and 41%, depending on the fossil fuel comparator.

de Souza et al. (2010) worked on GHG and energy balance of palm oil biofuel. This work assesses life cycle emissions and the energy balance of biodiesel production from palm oil in Brazil. A study on emissions and deposit characteristics of a small diesel engine operated on preheated CPO is conducted by Kalam and Masjuki (2004). Their experimental result carried out to evaluate exhaust gas emissions and deposit characteristics of a small diesel engine operated on preheated CPO and its emulsions with 1%, 2% and 3% water. It was observed that preheated CPO reduced CO, HC and PM compared to ordinary diesel (OD) and CPO emulsified fuel. This is mainly attributed to the fact that preheating of CPO reduces its viscosity to the level of OD that improves the fuel spray and atomisation characteristics and produces complete combustion. However, preheated CPO increased NOx emission as compared to OD and CPO emulsified fuels. This is mainly attributed from the deposit characteristic result, and shows that preheated CPO increased the highest fraction of ash deposit as compared to OD and CPO emulsified fuels, which is the reason for increasing NOx emissions. Again, another test on palm biodiesel and nonylphenoxy acetic acid (NPAA) to control NOx and CO while improving efficiency in diesel engines is investigated by Kalam and Masjuki (2008). The result shown that, NOx, CO and HC concentration decrease by using palm diesel with additive compared to diesel fuel and Palm biodiesel. Hence, the NPAA additive is effective in palm diesel fuel. From Fattah et al. (2014) experimental investigation, an effect of antioxidant on the performance and emission characteristics of a diesel engine fuelled with palm biodiesel blends is examined. Here, the effect of antioxidant addition to palm biodiesel on engine performance and emission characteristics is carried out. The results showed that, B20 and antioxidant-treated B20 produced 0.68~1.02% lower BP and 4.03~4.71% higher BSFC compared to diesel. Both of the antioxidants reduced NOx by a mean of 9.8~12.6% compared to B20. However, compared to B20, mean increases in CO and HC emissions of 8.6~12.3% and 9.1~12.0%, respectively were observed.
emission levels of the three pollutants were lower than those of diesel. Kousoulidou et al. (2010) studied the palm biodiesel blend effects on common rail diesel emissions and compared against a Euro-3 common-rail light duty vehicle. The results show that palm biodiesel blends reduced PM emissions and only marginal effects on NOx over the certification test. Ignition timing, fuel contents, spray technology, fuel viscosity, etc. has correlation with the emissions that occurs from engine. For reducing emissions; using of additives fuel properties by preheating or oxidising, many after treatment devices such as particulate matter filter, exhaust gas recirculation (EGR) could be used.

5 Advantages and limitations

There are several benefits of using palm oil biofuel. Some of the potential benefits are listed below:

- Palm biodiesel is renewable, biodegradable, non-toxic and safe to handle (flash point is higher than petroleum diesel) and essentially free of sulphur. It also provides a safety net to stabilise the price of palm oil by removing surplus stock (http://www.palmoilworld.org/biodiesel.html).

- Increasing demand of palm oil in different markets enhancing the use of palm biodiesel that contributes to the increased demand and thus helps to enhance palm oil prices.

- Palm oil biodiesel production and uses increasing new business and job opportunities in Malaysia and other countries. It also provides opportunity to extract phytonutrients such as carotenes (pro-vitamin A) and vitamin E (http://www.palmoilworld.org/biodiesel.html).

- Palm oil as biofuel itself, the wastewater ponds also present an intriguing new revenue possibility via 3rd generation biofuels, namely algae. Also, green plantations could more easily pick up the market share for environmentally friendly certified biofuels (Byun and Barrage, 2013).

- Various studies indicate that, using of biodiesel reduces sulphur dioxide, HCs, carbon monoxide and carbon dioxide emissions and particulate matters. Biodiesel has higher cetane numbers, which improves engine performance and reduce exhaust emissions compared to other petroleum diesel.

- Utilisation of palm biodiesel would generate an energy yield ratio of 3.53 (output energy/input energy), indicating a net positive energy generated and ensuring its sustainability. The energy ratio for palm biodiesel was found to be more than double that of rapeseed biodiesel which was estimated to be only 1.44, thereby indicating that palm oil would be a more sustainable feedstock for biodiesel production as compared to rapeseed oil. Moreover, combustion of palm biodiesel was found to be more environment friendly than petroleum-derived-diesel as a significant 38% reduction of CO2 emission can be achieved per litre combusted (Yee et al., 2009).

- Since CO2 is a greenhouse gas responsible for global warming, the world benefits by the burning of biofuels instead of fossil fuel. Additionally, the palm trees that produce oil have simultaneously absorbed a lot more CO2 during photosynthesis to
form biomass for the other part of the planet. The tree continues to absorb CO$_2$ throughout its life span of 25–30 years. So, palm biofuel is more than carbon neutral (Basiron, 2007).

- Palm biodiesel typically contributes to GHG emission savings of more than 70% compared to petroleum diesel if the biogas in the palm oil mill effluents is captured. If the biogas is emitted to the atmosphere, the GHG emission savings is more than 50%, as the Malaysian palm oil industry think. Moreover, biogas consists of 60% to 70% of methane, 30% to 40% of CO$_2$ and trace amount of hydrogen sulphide. Methane is 23 times more global warming potential as compared to CO$_2$ and thus contributes considerably towards GHG emission.

Besides these, there are several limitations and criticism arises oppose to use palm oil biofuel. Several scientific and environmental groups’ comments on the Environmental Protection Agency (EPA) proposed finding on palm oil. EPA’s analysis found that palm oil-based biodiesel fails to meet the minimum qualifying standard of 20% fewer GHG than conventional petroleum-based diesel for the renewable fuels standard (RFS), as well as the 50% GHG reduction to qualify as a renewable diesel. They argued that EPA’s analysis actually underestimates the GHG of palm oil and the serious environmental problems that palm cultivation creates. Expert scientists and researchers made their comments and opinions on emissions from palm oil biofuel. Dr. Jeremy Martin, Senior Scientist at the Union of Concerned Scientists said, “The emissions of palm oil-based biofuels substantially exceed the emissions from conventional petroleum diesel”. Glenn Hurowitz, Climate Advisers Director of Campaigns said, “If the palm oil industry wants to actually reduce its environmental impact and qualify for this mandate, the solution is simple: end deforestation for palm”. Glenn Hurowitz further said, “Palm oil is so polluting that it manages to make even dirty old oil look like an environmentalist dream” (Stark, 2012).

6 Conclusions

Palm oil is a great source of biofuel. Apart from that it has various uses such as CPO is the primary product derived from the red fruits of the oil palm, while palm kernel oil (PKO), derived from the fruit’s nut is considered to be a secondary product. Palm kernel meal (PKM) is primarily used for animal feed. It is one of the most efficient oil bearing crops in terms of land utilisation, efficiency, productivity and availability at competitive price. These are the important criteria for palm oil to be used as biofuel. Palm oil holds advantages over other oils and fats lies in its productivity, yield and efficiency factors. The yield of palm oil per unit area is 5 to 10 times higher than rapeseed and soybean oil, respectively. As the world is looking for alternative solutions through vegetable oils as renewable fuel, palm oil is undoubtedly stood out among other vegetable oils. Using palm oil as alternative fuel needs further study and research on biodiesel fuel property characteristic, long-term wear and tribological analysis along with injection timing and duration for better combustion in diesel engines need to be carried out. At the same time, in view of opportunities that presented by the biofuel industry, all stakeholders must be aware of the impact of their industries on environmental sustainability and be prepared to research and share experiences in this area.
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References


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