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RESEARCH ARTICLE

PRODUCTION OF BIODIESEL FROM WASTE DEEP FRYING OILS AS A RENEWABLE ENERGY SOURCE

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ABSTRACT

Biodiesel is a non-petroleum based fuel derived from vegetable oils or animal fats. Biodiesel has attracted huge attraction worldwide due to its renewability, biodegradability, and its better gas emission. The process of biodiesel production which converts vegetable oils and fats to fatty acid methyl ester using a short chain alcohol and catalyst called transesterification. A maximum of 92% biodiesel conversion obtained by using 1:4 oil/methanol ratio and catalyzed by KOH. Brake horse power and fuel consumption were found that increased with increased amount of biodiesel percentage in fuel blend. Engine power output was found to be decreased when biodiesel blend percentage increased. The objectives of this study are to investigate the optimize production of biodiesel from waste deep frying oil by using different amount of catalyst and different amount of oil-to-methanol ratio and to compare the engine performance of biodiesel and ordinary diesel when tested with diesel engine.

Key words: waste deep frying oil, biodiesel, transesterification, engine performance

INTRODUCTION

The depletion of fossil fuels, increasing demands for diesel and uncertainty in their availability is demanding an urgent need to carry out research work to find out the variable alternative sources of energy, which can replace fossil fuels. Biodiesel is one of the best available sources to fulfill world energy demand. Biodiesel is a nonpetroleum-based fuel defined as mono-alkyl esters derived from vegetable oils or animal fats. Biodiesel has attracted huge attraction worldwide due to its renewability, biodegradability, and its better gas emission. Biodiesel is essentially sulphur free and non-aromatic while conventional diesel can contain up to 500 ppm SO_2 and 20-40% aromatic compounds. Besides that, according to Utlu and Kocak (2008), there was average decrease of 14% for CO_2, 17.1% for CO and 22.5% for smoke density when using biodiesel on a diesel engine.

The process of biodiesel production called transesterification. Transesterification is the general term used to describe the important class of organic reaction where an ester is transformed into another through interchange of the alkoxy moiety. When the original ester is reacted with an alcohol, the transesterification is then called alcoholysis as shown in figure 1.Transesterificationprocess converts vegetable oils and fats to fatty acid methyl ester using a short chain alcohol and catalyst (Phan and Phan, 2008; Predojević, 2008). As shown in figure 2 (Ulf *et al.*, 1998), a by-product, glycerol, also known as glycerine is produced. Various oils like sunflower (Antolín *et al.*, 2002), palm oil (Edward *et al.*, 2001) algae (Hossain *et al.*, 2008) and soybean (Noureddini *et al.*, 1986) have been used in different countries for biodiesel production due to its availability. Edible oil as biodiesel production feedstock created a problem which is food shortage (Starbuck and Harper, 2009). Competing between biodiesel production and food production that causing the price of food to rise. Therefore, waste cooking oils as biodiesel feedstock gives better outcomes.

In Malaysia, large amount of waste cooking oils was produced from restaurant, catering establishment, and food industries every year. Therefore, the feedstocks have higher availability and cheaper cost. However, waste frying oils may contaminated by food residue and contain more water. Water and high content of free fatty acid in waste frying oil will react with base catalyst to produce soap. This side reaction also known as saponification process which consumes catalyst and lowers the biodiesel production yields (Hossain *et al.*, 2008). Thus, pretreatment steps needed to remove all contaminate and water content. Recent researches have used heterogeneous catalysts for higher biodiesel production yield and lower processing costs related to homogeneous catalysts ($Na/NaOH/KOH/\gamma\text{-}Al_2O_3$) (Trakarnpruk *et al.*, 2008). The objectives of this study are to investigate the optimize production of biodiesel from waste deep frying oil by using different amount of catalyst and different amount of oil to methanol ratio and to compare the engine performance of biodiesel and ordinary diesel when tested with diesel engine.

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Methodology

The biodiesel fuel used in this study was produced from waste deep frying oils obtained from a restaurant at Serian town, Sarawak, Malaysia. The waste oil was filtered by filter paper to remove food residue and then heated at 120^oC for 1 hour to remove water content. The transesterification reaction was carried out with methanol (CH_3OH) and catalyzed by potassium hydroxide (KOH) and sodium hydroxide (NaOH). Catalyst was dissolved in CH_3OH. The methoxide formed after all catalyst was fully dissolved in CH_3OH. Meanwhile, the waste oil was heated up to 60^oC. The oil was mixed with the methoxide and the solution was then shaken by using a shaker at a 150 rpm for 3 hours. After the reaction time, the mixture was poured into a separating funnel and allowed to settle down overnight. Two distinct layers were formed in a successful transesterification reaction. The ester layer located in the upper layer was separated by gravity. The glycerol, extra CH_3OH, catalyst and other undesired product were at the lower layer and were decanted. The ester layer was washed several times with distilled water until the washing water become neutral. The ester layer was then dried and stored. Biodiesel testing was carried out to compare the properties of biodiesel produced from waste deep frying oils with the conventional diesel. The engine used in this study was ISUZU-4FB1. The important engine specifications are given in Table 1. A variable speed range from 800 to 3600 rpm with 50% throttle setting was selected for engine performance tests.

(Fillipis *et al.,* 1995; Tomasevic *et al*., 2003), 7:1 – 8:1 using KOH (Phan and Phan, 2008) and 4.8:1 using sodium hydroxide (Felizardo *et al.,* 2006); while it could be up to 250:1 in the presence of acidic catalyst (Zheng *et al*., 2006). There is no optimal value of CH_3OH/oil ratio or catalyst/oil mass ratio. It depends on the reaction condition (such as temperature, pressure) and the source of oil and fats.

$$RCOOR' + R''OH \xrightleftharpoons{\text{catalyst}} RCOOR'' + R'OH$$

Fig. 1. General equation for a transesterification reaction

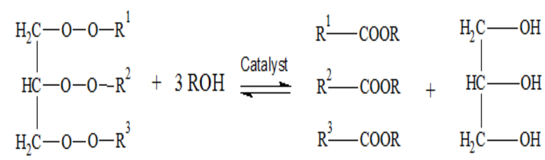

Fig. 2. Transesterification reaction

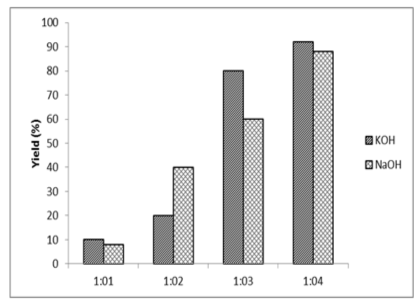

Fig. 3. Biodiesel production yield with various oil/methanol ratios, shaken for 3 hrs.

Table 1. Specification of diesel engine

Engine	: ISUZU
Model	: 4FB1
Type	: Water-cooled, four stroke
Combustion	: Indirect injection (IDI) and naturally aspirated
Number of cylinders	: 4
Bore × Stroke	: 84 × 82 mm
Displacement	: 1817 cc
Compression Ratio	: 21 : 1
Nominal Rated Power	: 39 kW/5000 rpm
Maximum Torque speed	: 1800 – 3000 rpm
Dimension ($L \times W \times H$)	: 700 × 560 × 635(mm)
Weight (dry)	: 185 kg
Combustion Chamber	: Swirl Chamber
Nozzle Type	: Throttle
Governor Type	: Mechanical, variable speed, min-max speed
Cooling System	: Pressurized circulation

RESULTS AND DISCUSSION

Biodiesel production

Oil/methanol ratio plays an important role on biodiesel production yield. Figure 3 shows the biodiesel production yield with various oil/methanol ratios. The results obtained shown that 1:4 gives highest yield for both KOH and NaOH, 92% and 88% respectively. Therefore, amount of methanol used more than the stoichiometric ratio increase biodiesel production yield. The excess methanol will drive the equilibrium toward ester production. However, increase amount of methanol will affect the separation process of ester from glycerin because there is an increase in solubility (Murugesan *et al.,* 2009). When glycerin remains in the solution, the equilibrium shifted backward, hence is lowering the yield. Previous researchers had obtained maximum conversion using different CH_3OH/oil ratio such as 6:1

Engine performance tests

Brake horse power (BHP) is the amount of power generated by a motor without taking into consideration any of the various auxiliary components that may slow down the actual speed of the motor. Figure 4 shows the variation in brake power output with different biodiesel blends. B50 (50% of biodiesel blended with ordinary diesel by volume) has the highest brake power among all biodiesel blends followed by B40, B30, B20, B10 and B0 (ordinary diesel) at all engine speeds. The brake power outputs of biodiesel blends are slightly higher than normal diesel. The increase in brake power of biodiesel blend is due to the effect of addition of lube oil in blends. Addition of lube oil enhances better spray characteristics and thus increases fuel conversion efficiency through the complete combustion (Kalam *et al.,* 2002). The brake horse power was increased at lower engine speed until a maximum at 1600 rpm. After that, the brake horse power decreased when reached higher engine speed. The maximum brake horse power was obtained at 1600 rpm for all kind of fuels. At 1600 rpm, B10, B20, B30, B40 and B50 produced 10.169 kW, 11.122 kW, 12.467 kW, 12.901 kW and 14.177 kW respectively whereas ordinary diesel produced 9.147 kW. Ordinary diesel is use as a base for comparison. From the trend obtained, the performance of biodiesel blends was similar to ordinary diesel.

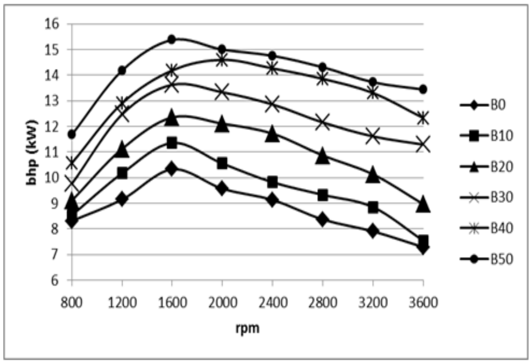

Fig. 4. Brake horsepower (kW) vs. engine speed (rpm) of various biodiesel blends

Figure 5 shows the engine power output between biodiesel blends and ordinary diesel at brake load of 120 N and ¾ throttle position at engine speed of 1600 rpm. The results show that the measured engine power outputs of biodiesel blends are slightly lower than ordinary diesel. The engine power output decreases with the increase of percentage of biodiesel blend. Ordinary diesel produced the maximum engine power output (2.072 kW) followed by B10 (2.035 kW), B20 (2.025 kW), B30 (1.998 kW), B40 (1.956 kW), and B50 (1.918 kW). At the speed of 1600 rpm, the difference of the measured engine output between ordinary diesel and B10, B20, B30, B40 and B50 fuels found to be 1.8%, 2.3%, 3.6%, 5.6% and 7.4%, respectively. Lower heating value of the biodiesel is the main reason for the reduction of engine power output as compare to petroleum based diesel. Kaplan *et al*. (2006) and Buyukkaya (2010) also explained this power reduction with lower heating value of the biodiesel.

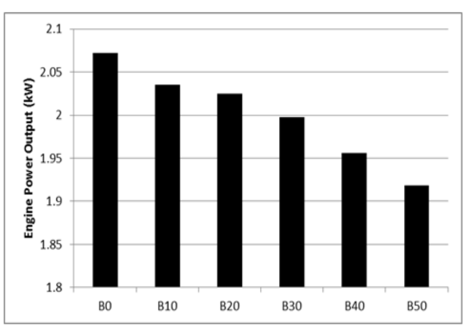

Fig. 5. Engine power output (kW) of various biodiesel blends at 1600 rpm.

Figure 6 shows the fuel consumption of various biodiesel blends at engine speed of 1600 rpm. Fuel consumption of the biodiesel blends was observed to be higher than that of ordinary diesel. At the speed of 1600 rpm, the difference of the measured fuel consumption between ordinary diesel and B10, B20, B30, B40 and B50 found to be 2.6%, 6.7%, 12.7%, 21.2% and 37.9% , respectively. The increase in fuel consumption is because of the lower heating value and higher density of biodiesel as compare to ordinary diesel (Ming *et al*., 2008). Hence, fuel consumption increase as the biodiesel percentage blended in fuel increase.

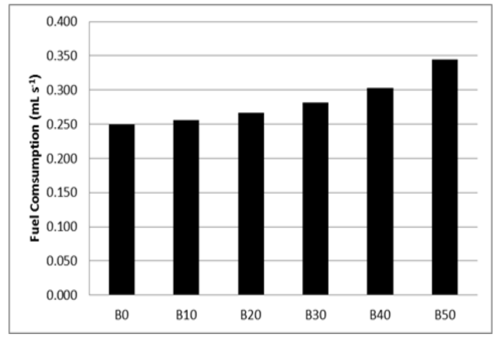

Fig. 6. Fuel consumption (mL s^{-1}) of various biodiesel blends at 1600 rpm.

Conclusion

In this study, biodiesel is produced from waste deep frying oils that collected from restaurants. Oil to methanol ratio that is more than stoichiometric ratio was used to obtain optimum production yield. A maximum production percentage of 92% obtained by using 1:4 oil-to-methanol ratio and catalyzed by KOH. Brake horse power and fuel consumption were found that increase with increased amount of biodiesel percentage in fuel blend. Essngine power output was found to be decrease when biodiesel blend percentage increase. Therefore, it can be concluded that biodiesel blend percentage of 10%-20% is more applicable.

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