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WASTE FISH OIL BIODIESEL PRODUCTION AND ITS PERFORMACE IN DIESEL ENGINE

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ABSTRACT

Waste Fish oil was used as raw material for biodiesel production. Two stage process, esterification and transesterification were applied to convert waste fish oil to biodiesel. An acid catalyst (H_2SO_4) and alkaline catalyst were used for catalysts of the esterification and transesterification, respectively. Fish oil, methanol or ethanol, and catalyst were reacted in a three-neck flask at temperature at 60 °C and time of 2 h. The effect of alcohol types on biodiesel conversion showed that the optimum condition (conversion of 66.09%) was obtained using methanol. The density, kinematic viscosity, heating value of fish oil biodiesel was 0.8822 g/mL, 4.741 mm^2/s. 9713 cal/g, respectively. The biodiesel was tested on diesel engines to determine the engine torque, power and Brake Specific Fuel Consumption as compared to diesel oil. At lower speed engine of 1200-1400 rpm, the engine torque of waste fish oil biodiesel and diesel oil was higher than that at higher speed engine of 1400-1500 rpm. Blendings of waste fish oil had higher engine torque than that of diesel oil. Blends fuel of waste fish oil biodiesel had higher power engine as compared to that of diesel oil fuel at speed of 1200-1500 rpm. Blends waste fish oil biodiesel had lower BSFC (Brake Specific Fuel Consumption) as compared to that of pure diesel oil.

Keywords: biodiesel, waste fish oil, esterification, transesterification, diesel engine performance.

INTRODUCTION

The higher consumption of diesel oil have caused the scarcity of petroleum and increasing its cost. The efforts have been performed to develop alternative fuels especially, to the diesel oil for fully or partial replacement. The vegetable oils have been found to be promising fuels because their properties are similar to that of diesel and are produced easily and renewably from the crops. Compare to the diesel fuel, vegetable oils have comparable for its energy, cetane number, heat of vaporization and stoichiometric air–fuel ratio. However, vegetable oils have much higher viscosity than that of diesel oil [1]. Many researchers have conducted the transesterification reaction to convert vegetable oils become biodiesel. Biodiesel have several great advantages than that of diesel fuel such as renewable, biodegradable, non-toxic, and essentially free of sulfur and aromatics. Biodiesel has environmental benefits due to the neat or blends biodiesel can reduce carbon monoxide (CO) emissions, hydrocarbons (HC), particulate matter (PM), and increase nitrogen oxides (NOx) emissions compared with diesel fuel used in an unmodified diesel engine [2]. The prices of edible vegetable oils are higher than that of diesel fuel; therefore, waste vegetable oils and non-edible crude vegetable oils receive more attention over the edible vegetable oils for biodiesel production [3]. There are some very low quality vegetable oils as biodiesel feedstocks, such as trap grease, used cooking oils, animal oils that contains significant amounts of free fatty acids (FFAs). Used cooking oils typically contain 2-7% FFAs, and animal fats contain from 5% to 30% FFAs. A pretreatment is required to reduce the FFA level, then the low FFA pretreated oil can be transesterified with an alkali catalyst to convert the triglycerides to biodiesel [4]. Encinar *et al*. (2005) studied the production of biodiesel from used frying oil by two step reactions. The characteristic of biodiesel had the density; viscosity, cetane index, and higher heating value were similar to those of diesel oil. However, the cloud and pour points were higher, which results the difficulties in cold starts. On the other hand, the flash and combustion points were higher than those of diesel oil, which constituted a safety guarantee from the point of view of handling and storage [5]. Altiparmark *et al*. (2006) used crude tall oil, a by-product in the manufacture of paper pulp, for biodiesel production. The blends of tall oil biodiesel-diesel fuel were tested in diesel engine at full load condition. The engine performance and exhaust emission showed that the engine torque and power output with tall oil biodiesel-diesel fuel blends increased up to 6.1% and 5.9%, respectively as compared to pure diesel oil. The decreased of CO emissions to 38.9% and increased up of NOx emissions to 30% of biodiesel fuel blends were observed [6].

The most obstacle of biodiesel is the higher cost of biodiesel as compared to conventional diesel fuel. The high cost of processing biodiesel is due to the price of feedstock from edible vegetable oil is expensive. To reduce the biodiesel cost, a potential feedstock, waste vegetable oil from restaurants and rendered animal fats can be used. Waste vegetable oils and fats are generally low in cost and are currently collected from large food processing and service facilities [7]. El-Mashad (2008) used salmon oil, a by-product of salmon processing, as a feedstock for biodiesel production via transesterification in a two-step process. A two-step process consisted of firstly pre-treated with an acid-catalysed reaction for reducing the acid value and then followed by tranesterification using KOH as the catalyst for yielding biodiesel [8]. Narasiman

et al., (2012) studied the performance and emission characteristics of diesel engine using neat sardine oil with vary blends with diesel oil. The decreased in brake thermal efficiency and increased CO (Carbon-monoxide), HC (Hydro-Carbon) in the exhaust was observed using neat sardine oil compared to diesel except NOx (Nitrogen Oxide) [9]. Narasiman *et al.* (2012) reported various blends of sardine oil biodiesel on the performance and emission characteristics of the diesel engine. The results showed that the specific fuel consumption than diesel for all blends [9].

Table-1. Characteristic of biodiesel from waste fish oil.

No.	Characteristics of biodiesel	Waste fish oil biodiesel	Used cooking oil biodiesel (Dorado, 2003) [10]	Methods
1.	kinematicviskosity at 40°C, mm²/s	4.741	5.29	ASTM D 445-07
2.	FlashPointP.M., °C	184.5	169	ASTM D 93-07
3.	Density pada 15°C, g/mL	0.8822	0.8823	ASTM D 1298
4.	Cloud Point, °C	12	0	ASTM D 97-07
5.	ConradsonCarbonResidue, %wt.	0.0016	0.3	ASTM D 189-07
6.	CaloriValue, cal/g	9713	9394.1	Bomb Calorimeter

In this study, the production of biodiesel using methanol, sulphuric acid and sodium hydroxide in a two stage process from waste fish oil were studied. The characteristic properties of waste oil biodiesel including kinematic viscosity, flash point, density, cloud point, coradson carbon residue, caloric value were determined.The effects of the waste fish biodiesel addition in different proportions to diesel oil on the performance of a four cycle, one cylinder Diesel engine were investigated.

MATERIALS AND EXPERIMENTAL METHOD

Fish waste the form of a fish head, gills, heart and stomach of fish was collected from a traditional market in PasarGede Surakarta. An analytical grade chemicals methanol, ethanol, H_2SO_4, NaOH were used. A reaction of esterification–transesterification processes were conducted in a three-neck flask equipped with a condenser and strring equipment.

Preparation of Fish Oil

3 kg fish waste in the form of a fish head; gills, heart and stomach of fish were washed. After that, the fish waste was added with water as a solvent and it was boiled. The result of boiling fish waste was the oil layer that formed on the upper stew of fish waste. Oil was then taken and put into separation funnel to separate it from the solvent. After the fish oil could be separated with solvent, about 150-200 mL oil was gained. The oil could be used as raw material for biodiesel production or stored in sealed glass bottles.

Biodiesel Production from Waste Fish Oil

The first step was to reduce FFA content of the waste fish oil by the esterification process that was carried out using 1kg waste fish oil, methanol (at the oil-to-methanol molar ratio of 1:6) and 2% H_2SO_4 as acid catalysts. The mixture was esterified at constant temperature of 60 °C for 2 h with stirring speed 600 rpm. The esterification process yield the liquid product with two distinct layers. The oil was washing with water then it was separated in separating funnel and remaining water was removed by heating. Then, the oil was dissolved in methanol (molar ratio oil to methanol 1: 6) and 2% NaOH. The oil, NaOH and methanol mixtures were transesterified for 60 minutes at temperature and speed of stirring 60 C and 600 rpm, respectively. Then, the process was stopped where the liquid products having two layers, the top layer containing the methyl ester/biodiesel and the bottom layer containing glycerol. Biodiesel was taken from the reaction products using separating funnel for 1 hour. It was purified by washing with distilled water then shaking for 5 minutes. The washing process was carried out in 3 times. Then, biodiesel was dried in an oven at 90 ° C to remove the water content.

Analysis of Biodiesel

Biodiesel of waste fish oil was determined for its kinematic viscosity, flash point, density, cloud point, coradson carbon residue using ASTM methods and caloric value using Bomb Calorimeter.

Diesel Engine Performance

For this experimental study, biodiesel blends and diesel oil fuels performances were conducted on single cylinder engine, maximum power 2200 rpm, direct injection diesel engine, engine speed changed from 1250 to 1450 rpm, model ER/KND 180 (Kubota).

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RESULTS AND DISCUSSIONS

Characteristics of Biodiesel

The waste fish oil biodiesel characteristic was determined using ASTM method. The characteristic properties of biodiesel as a fuel was determined including kinematic viscosity, flash point, density, cloud point, coradson carbon residue, caloric value.

Table-1 shows the characteristic of waste fish oil biodiesel compared to used cooking oil biodiesel based on work studied by Dorado (2003)[10]. It shows that characterictic of used cooking oil biodiesel were comparable with that of waste fish oil biodiesel. The density of 0.8822 g/mL for waste fish oil biodiesel was closer to 0.8823 g/mL for used cooking oil biodiesel. The kinematic viscosity from waste fish oil biodiesel of 4.741 mm^2/s was lower to 5.29 mm^2/s for used cooking oil biodiesel. It indicates that the lower viscosity of waste fish oil biodiesel is suitable for fuel. Biodiesel from rubber seed oil, sun flower oil, rape seed oil, cotton seed oil, soybean oil, and diesel had viscosity (mm^2/s) of 5.81, 4.5, 4.5, 4.0 , 4.08, 3.8, respectively and calorific value (MJ/kg) of 36.50, 40.56 , 37.00, 40.32 39.76, 42.50, respectively (Ramadhas *et al.,* 2005) [1]. It has reported that a higher kinematic viscosity of fuel can cause an extinction of flame as well as the increase in carbon deposits and engine emissions.

Waste fish oil biodiesel had a lower Coradson carbon residue (0.0016 wt%) compared to used cooking oil biodiesel (0.3% wt). The higher carbon residue will give negative impact which results an increase carbon deposited in the combustion chamber which can reduce the engine performance. Heating value of waste fish oil biodiesel was higher (9713 cal/g or 40.67 MJ/kg) than that of used cooking oil biodiesel (9394.1 cal/g). However, the flash point of biodiesel fish oil was higher (184.5 °C) than that of used cooking oil biodiesel (169 °C). It also affects the performance of engine as the higher flash point can reduce the starting of biodiesel burning.

From the analysis results of ASTM, the characteristics of waste fish oil biodiesel are comparable to those of used cooking oil biodiesel. Thus, the waste fish oil can be used as an alternative raw material for biodiesel production. It has been reported (Demirbas (2005) [2] that vegetable oil has density in the ranges between 902.6 and 923.6 kg/m^3. While the density of waste fish oil biodiesel in this study was 882.3 kg/m^3. The decreasing density of waste fish oil biodiesel compared its vegetable oil was due to the transesterification reaction that convert triglycerides of waste fish oil to form methyl ester or biodiesel. The viscosity of vegetable oil is higher in the range between 27.2 and 53.6 mm^2/s, than waste fish oil biodiesel has density between 3.59 and 4.63 mm^2/s. The calorific value of biodiesel is between 9-13% which lowers than the calorific value of diesel oil, it causes affected to the performance of biodiesel where the energy output from biodiesel is smaller and the fuel consumption is greater as compared with the conventional diesel fuel.

Performance of diesel engine using blending fuel of waste fish oil biodiesel and diesel oil

In this study, the blends of waste fish oil biodiesel and diesel fuel were mixed in the ratios of 15:85, 20:80, and 25:75 (v/v) which known as B15, B20, and B25. Then the blends fuel was tested in a diesel engine to determine its engine torque, power, and break specific fuel consumption. The relationship between the engine torque, power, and specific fuel requirements for blending fuel and diesel oil as follows:

Engine Torque

The experiment result of engine torque at different speed engine (1200-1450 rpm) are shown in Figure-1, the blending of waste fish oil biodiesel and diesel oil lead to increased of the engine torque as compared to that of the diesel oil at 1200-1450 rpm. The highest of engine torque was obtained for blending fuel with a blend of 25% waste fish oil biodiesel and 75% diesel oil (B25). Usta *et al*. (2005) reported the effects of the biodiesel on the engine torque for engine speed 1500 and 3000 rpm found that the power of biodiesel blend was slightly higher than the diesel at all loads in the test speed range[3]. The increased of engine torque due to the density and mass flow rate of the biodiesel blend were higher than diesel fuel. Altiparmak *et al*. (2006) reported that at higher engine speeds, a slight increase in torque was obtained with the blended fuels and the blend fuel of 30% diesel-70% biodiesel showed the maximum torque due to the higher cetane number of the blended fuels [6]. It has been reported by Demirbas (2005) that the engine torque of biodiesel was lower than that of diesel oil at low speed engine which resulted in the decreasing engine power at about 5% [2].

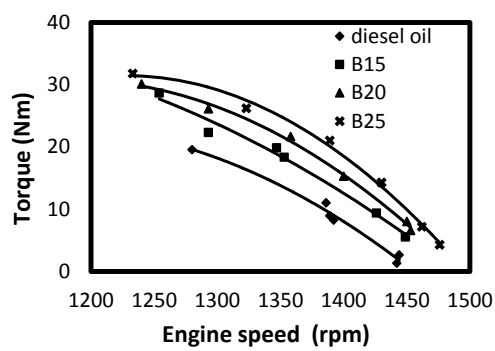

Figure-1. The effect of biodiesel blends fuel and diesel oil on performance engine Torque.

Engine Power

The experiments was carried out to test an engine power using blending fuels of waste fish oil biodiesel and diesel oil as shown in Figure-2. An inceased of engine speed from 1200 to 1500 rpm showed a lower engine

power for the blending fuels and diesel oil. It can be seen that blending fuel of waste fish oil biodiesel had higher power engine as compared to diesel fuel at speed of 1200-1450 rpm. Work studied by Usta *et al*. (2005) showed that addition biodiesel from 5-25 % resulted an increased the power with the addition of biodiesel, reached a maximum value at 20% biodiesel, and then decreased with further increase of the biodiesel content to 25% [3]. The result was due to the biodiesel contained approximately 10% (in weight) oxygen that could be used in combustion, especially in the fuel rich zone to get a complete combustion, thereby increasing the torque and power. Moreover, the addition biodiesel content more than 25% to diesel oil, the power would decreased below that of the Diesel fuel due to the lower heating value and the higher viscosity, which resulted in slightly poorer atomisation and poorer combustion[3]. Altiparmark (2006) reported that at low speeds, diesel fuel and the blends had similar engine power. However, at high engine speeds all fuel blends had increased its engine power compared to diesel [6].

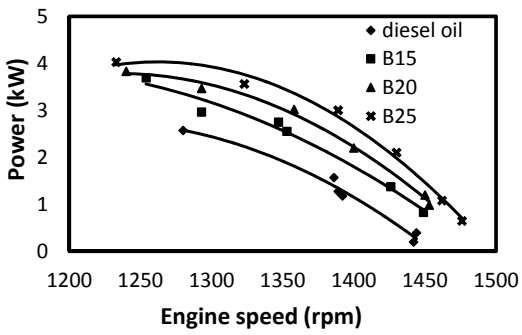

Figure-2. The effect of biodiesel blends oil and diesel oil on performance of engine power.

Brake Specific Fuel Consumption (BSFC)

From the experiments results in Figure 3, it can be seen that blending fuel of waste fish oil biodiesel and diesel oil has a lower BSFC as compared to that of pure diesel oil. The lowest BSFC was obtained for blending fuel of 25% waste fish oil biodiesel and 75% diesel oil (B25). Usta et al. (2010) reported the brake specific fuel consumption (bsfc) of various diesel fuel and the blend with different engine speed[3]. The result showed that the BSFC values of the blend were slightly higher than those of the diesel fuel. The BSFC was dependent on the fuel injection system, volumetric, specific material weight, viscosity and heating value on biodiesel blending fuel, thereby more blending were need for producing the same amount of energy as the biodiesel fuel has higher specific gravity and lower calorific value compared with a fuel diesel. Ramadhas *et al.* (2005) reported that the brake specific fuel consumption of the engine was lower at lower percentage of biodiesel in biodiesel–diesel blends than that of diesel [1]. However for B50 to B100, the brake specific fuel consumption was higher than that of diesel. That results due to an increase in biodiesel percentage in the blends, the calorific value of fuel decreased that resulted the specific fuel consumption of the higher percentage of biodiesel in blends increased as compared to that of diesel. Altiparmark *et al.* (2006) reported that the bsfc increased up to 10.4% using blended fuels; however bsfc were decreased at high engine speeds [6].

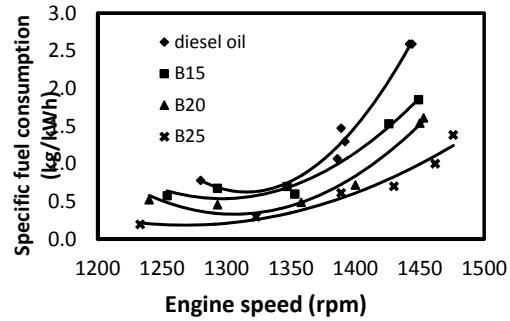

Figure-3. Effect of biodiesel blends fuel and diesel oil on brake specific fuel consumption.

CONCLUSIONS

Oil from fish waste can be used as raw material for biodiesel, the process of which is carried out in two stages. The first stage is the esterification process with an acid catalyst (H_2SO_4) to lower the acid value oil and the second one is transesterification process with alkaline catalyst (NaOH) to change the oil into biodiesel. The optimum conversion of 66.09% was obtained at temperature of 60 ° C for 4 hours, the stirring speed of 600 rpm. The biodiesel produced can be applied to diesel machine with optimum mix of B25 (Biodiesel 25% and Solar 75%). The viscosity values of waste fish oil was 4.71 mm^2/s whereas those of used cooking oil biodiesel was 5.29 mm^2/s. The flash point values of waste fish oil biodiesel was 184.5 °C while °C for used cooking oil biodiesel. The density of 0.882 and 0.8823 g/ml were obtained from waste fish oil and used cooking oil biodiesels. Waste fish oil biodiesel blends fuel have higher torque and power compared to those diesel oil. Waste fish oil biodiesel blends fuel has lower Brake Specific Fuel Consumption compared to that diesel oil.

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