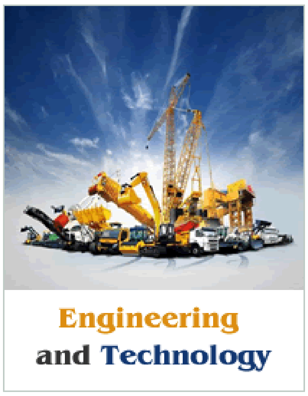
Engineering and Technology
2015; 2(5): 324-328
Published online July 20, 2015 (http://www.aascit.org/journal/et)

American Association for Science and Technology



Keywords
Palm Oil Biodiesel,
Blending,
Ethanol,
Diesel,
Fuel Properties

Received: June 27, 2015
Revised: July 2, 2015
Accepted: July 3, 2015

Improvement of High Blend Palm Biodiesel-Diesel Fuel Properties Using Ethanol Additive

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Citation
Obed M. Ali, Rizalman Mamat. Improvement of High Blend Palm Biodiesel-Diesel Fuel Properties Using Ethanol Additive. *Engineering and Technology*. Vol. 2, No. 5, 2015, pp. 324-328.

Abstract
As the fossil fuel price keeps rising and its reserves keep depleting, the uses of fossil fuel for transportation and or industries should be minimized and replaced by an alternative fuel as much as possible. Blended biodiesel fuel is considered as alternatives to current fossilized fuels at a low blending level less than 30% biodiesel. The fuel physical characteristics are among the most important parameter to determine the quality of each fuel. Though biodiesel can replace diesel satisfactorily, problems related to fuel properties persist at high blending ratio. In this study an oxygenated additive ethanol (E) was added to palm oil biodiesel (POME)-diesel blend B40 (40% vol. POME + 60% vol. diesel) in the ratios of 1%, 2%, 3% and 4% and tested for their properties improvement. These blends were tested for energy content and various fuel properties according to ASTM standards. Qualifying of the effect of additive on palm biodiesel-diesel blended fuel B40 properties can serve the researchers who work on biodiesel fuels to indicate the fuel suitability for diesel engines according to fuel standards. The results showed an improvement in acid value, viscosity and density. The maximum reduction in pour point for the blended fuel was 2 ^{o}C at B40-E3, while maximum decrease in energy content was about 6.6% for B40-E4 compare to blended fuel B40.

1. Introduction

Biodiesel has received a great deal of attention because of the advantages associated with its biodegradability and its classification as a resource for renewable energy [1]. Biodiesel is composed of fatty acid methyl esters (FAME) and is synthesized usually via vegetable oils (triacylglycerols) trans esterification with low-molecular-weight alcohols [2]. The current mandates regarding the use of biodiesel around the world are mostly based on a biodiesel–diesel blend up to 20% biodiesel. The additive is the most visible option to introduce the biodiesel–diesel blended fuel at hight biodiesel blending ratio as alternative fuel for mineral diesel.

The availability and sustainability of biodiesel feedstocks will be the crucial determinants in the popularization of biodiesel [3]. The oil palm is a tropical perennial plant and grows well in lowland with humid places. Compared with other biodiesel feedstocks, oil palm is the highest oil yield crop, producing on average about 5950 litre of oil per hectare annually. Sunflower, canola, soybean, and jatropha can only produce up to 952, 1190, 446, and 1892 litre of oil per hectare annually, respectively [4]. From the literature, it has been found that feedstock alone represents 75%-80% of the overall biodiesel production cost [5]. Therefore, selecting the high oil yield feedstock is vital to ensure low production cost of biodiesel.

Fuel injection systems measure fuel by volume, and thus, engine output power influence by changes in density due to the different injected fuel mass [6]. Thus, density is important for various diesel engine performance aspects. The use of fuel with a high kinematic viscosity can lead to undesired consequences, such as poor fuel atomization during spraying, engine deposits, wear on fuel pump elements and injectors, and additional energy required to pump the fuel [7]. The fuel energy content has a direct influence on the engine power output [8], [9]. The biodiesel energy content is less than that of mineral diesel, therefore using of additive most not worsen the energy continent of the POME fuel. Use of additive that have less energy continent with blended fuel usually causes the energy content of the fuel to decrease depending on the additive energy continent and portion. Currently, the energy content is one of the major technical issues in the use of biodiesel–diesel blends, as it relates to the engine power. The conducted researches on measuring the energy content very little and didn’t indicate the methods and equipment’s used for measurement. However, information concerning the energy content of palm oil biodiesel and its blending with additive remains scarce.

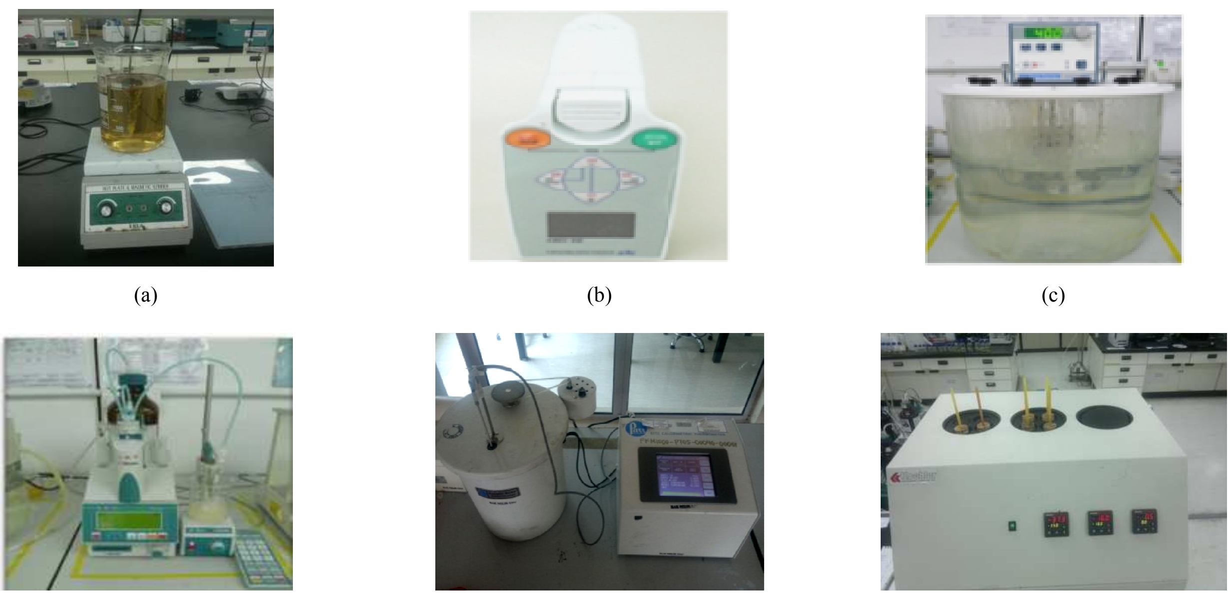
Studies [10], [11] on blended of ethanol and biodiesel prepared from Madhuca indica oil (MME) and poultry fat (PFME) exhibited better fuel properties versus unblended biodiesel. Where the reduction in cloud point and pour point was 4 oC and 3 oC for MME and 6 ^{o}C and 4 ^{o}C for PFME respectively, when blended with 20% of ethanol, with reduction in CO, lower NOx emissions and decrease in smoke emissions on an average without affecting the thermal efficiency.

Other experimental investigations [12], [13] were conducted to evaluate the effects of using ethanol as additives to soybean biodiesel/diesel blends on the performance, emissions and combustion characteristics of a direct injection diesel engine. The tested fuels denoted as B20E5 (20% biodiesel and 80% diesel in vol.) with 5% ethanol and (B30E5) 30% biodiesel and 70% diesel in vol.) with 5% ethanol. The results indicate that, compared with blended fuel, there is slightly lower brake specific fuel consumption (BSFC). Drastic reduction in smoke is observed with ethanol at higher engine loads. Nitrogen oxide (NOx) emissions and hydrocarbon (HC) emissions are slightly higher for blended fuel with ethanol, but carbon monoxide (CO) is slightly lower. However, the blended fuels with ethanol could lead to reduction of both NOx and HC emissions of a diesel engine [14], where biodiesel was blended with 5%, 10% and 15% by volume of ethanol and tested in a 4-cylinder direct-injection diesel engine.

Palm biodiesel-diesel blends up to B30 can be directly used in the diesel engines with little or no engine modifications [15]. Therefore, the objective of this study was investigated the ability of using the blended fuel B40 as alternative fuel for mineral diesel through characterize the properties of (POME)-diesel blends fuel (B40) with ethanol (E) as additive, including the energy content and law temperature flow properties.

2. Research Methodology

There were five samples of fuel used in this study which includes, blended fuel (B40) (biodiesel 40% blend with 60% mineral diesel), B40-E1, B40-E2, B40-E3 and B40-E4. Fig. 1 illustrates different analytical apparatus to measure the fuel properties. All the test methods conform to the strict ASTM procedures as recommended by manufacturers. Those tests were conducted under controlled room temperature, pressure and relative humidity to ensure that the result is not influenced from environmental errors.



(a) (b) (c)

(d) (e) (f)

Figure 1. *Analytical instruments used to measure fuel properties; (a) Magnatic stirrer, (b) Density meter, (c) Viscosity bath, (d) Acid value & acidity tester, (e) Oxygen Bomb Calorimeter, (f) Cloud and pour point measuring equipment .*

3. Result and Analysis

3.1. Viscosity

The viscosities of blended fuel vary in the range of 3.56 and 3.97 mm^2/s for B40-E4 and B40 respectively. All B40-E blends, as well as B40, satisfied the kinematic viscosity specification contained in ASTM D6751. The viscosity of the blend decreased linearly as the E portion increases in the fuel mixture as observed from Fig. 2. It clearly shows that the viscosity of B40-E4 was 10% lower than the blended fuel B40. This because the effect of E additive on free fatty acid (FFA) concentration in biodiesel. As a comparison, the small amount of ethanol dilution in the biodiesel blend fuel is proven to reduce the viscosity of the fuel.

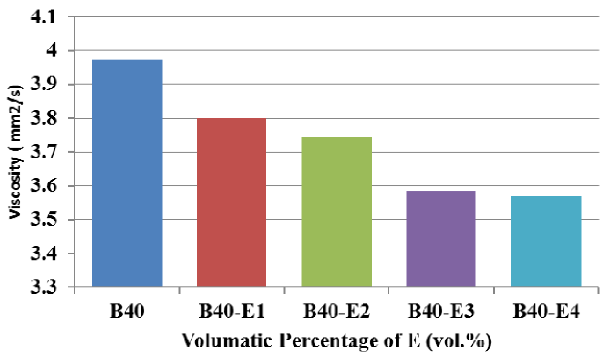


Figure 2. *Variation of viscosity.*

3.2. Density

The densities of B40-E blended fuel produced in this study are very close to each other and in the range of 857.2–860 kg/m^3 for B40-E4 and B40 respectively. They are suitable for the ASTM and EN standards and slightly higher than those of the diesel fuel 847 kg/m^3. Fig. 3 presents the variation of density values for B40 with E portion. It is clear that the density of the B40-E blend decreased linearly with a higher volumetric percentage of the E, indicating that the additivity for the volume.

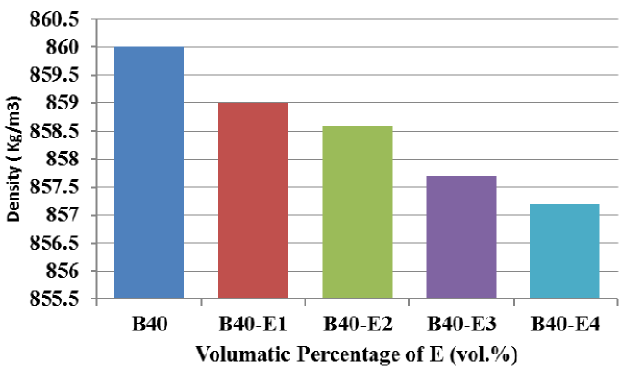


Figure 3. *Variation of density.*

From the figure it's obvious that the small amount of ethanol dilution in the biodiesel blend fuel is proven to reduce the density of the fuel closer to that of diesel fuel.

3.3. Acid Value

Acid value number is defined as the amount of potassium hydroxide (KOH) in milligrams that is necessary to neutralize free fatty acids (FFAs) contained in 1 gram of oil. It possesses as the vegetable oil quality indicator to monitor the oil degradation during storage period. According to ASTM D 6751 and EN14214, the maximum value of acid number is 0.5 mg KOH/g [16].

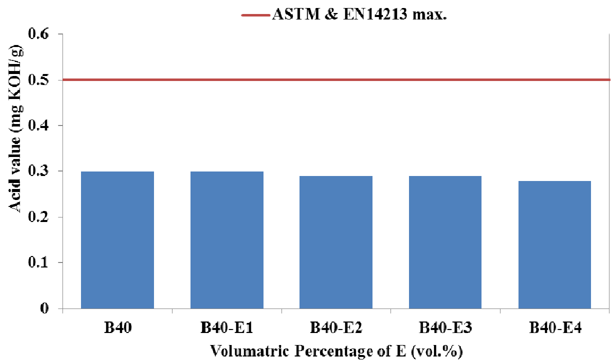


Figure 4. *Variation of acid value.*

Fig. 4 presents the acid value for the tested fuels. It can be seen from the figure that the number of acid value for B40 is the highest at 0.3 mg KOH/g. On the other hand, the number of acid value for B40-E4 is the lowest at 0.28 mg KOH/g. From figure it's clear that the acide value slightly improved by adding ethanol additive with the mentioned percentage. This was expected, as E will dilute the free fatty acids present in POME, resulting in a reduction in AV. The acid value of the B40-E blend satisfies the requirement of ASTM D6751-06 and EN 14104 Standard for all blending range.

3.4. Pour Point

B40-E blends improved low temperature operability compared to blended fuel B40 since the freezing points of E (-117.4 °C) are substantially below the temperature at which biodiesel typically undergoes solidification.

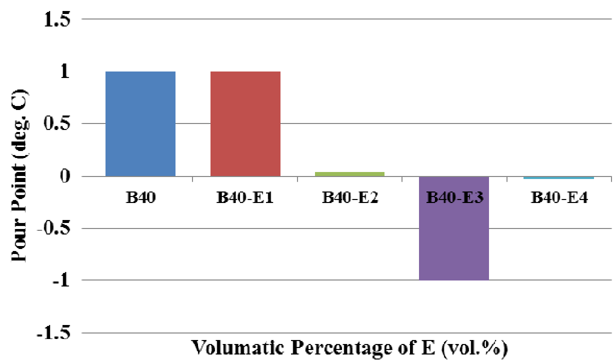


Figure 5. *Variation of pour point.*

Addition of E to blended fuel B40 slightly affected CP, while increasing E content from 0 to 4% resulted in a significant decline in PP. Fig. 5 shows the variations of the PP for POME with the volumetric percentage of the E. The maximum reduction of PP for blended fuel B40 was 3 ^{o}C when adding 3% E. The low-temperature properties of biodiesels not indicated in ASTM and EN standards as it related to climatic conditions.

3.5. Calorific Value

Due to its high oxygen content, biodiesel has lower mass energy values than petroleum diesel. Therefore, using low energy continent additive with blended fuel results in decreasing energy content of the fuel. The heating value is not specified in the biodiesel standards ASTM D6751 and EN 14214 but is prescribed in EN 14213 (biodiesel for heating purpose) with a minimum of 35 MJ/kg [17]

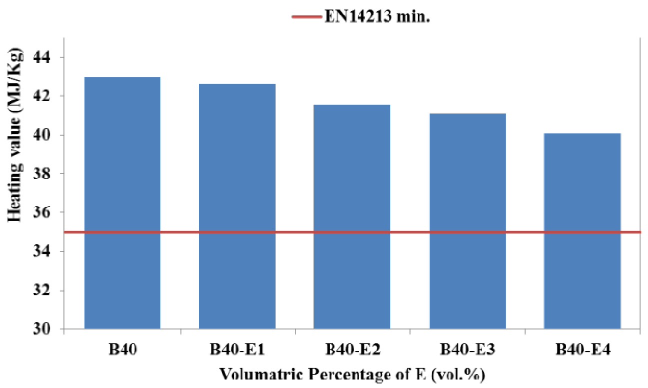


Figure 6. *Variation of energy content.*

Fig. 6, presents the calorific value of the fuels measured by Oxygen Bomb Calorimeter (refer to Fig. 1e). It can be seen from the figure that the calorific value of blended fuel B40-E4 is lower than that of blended fuel B40 by about 6.67%. From the figure it's obvious that the small amount of ethanol dilution in the biodiesel blend fuel is proven to slightly reduce the calorific value compare to that of Blended fuel.

4. Conclusion

The ability of using blended fuel B40 as alternative fuel for mineral diesel fuel was investigated through improving the blended fuel properties using small portion of ethanol as additive. From the study we have been concluded the following resultes:

1. An increase in ethanol additive concentration was linearly decreased the density and viscosity of the blend fuel closer to minerial diesel.
2. A small concentration of ethanol slightly improved the acid value of the blended fuel B40, where acid value decreased with the additive portion increasing.
3. In general, the heating value decreases slightly with increasing ethanol portion in the blends. The maximum decrease in heating value was about 6.6% at 4% ethanol additive compare to the blended fuel B40, which still satisfy the limits of the EN 14213 standard.
4. Increasing ethanol content in blended fuel B40 resulted in a significant difference in low temperature performance, with Maximum decrease in pour point by 2 ^{o}C for B40-E3 compare to B40.
5. Finally, B40-E3 blends exhibited slightly superior low temperature performance, acid value; viscosity and density with slight lower energy continent by about 4.3% compare to B40 and may be suggested as prudent choice suitable for diesel engine.

Acknowledgements

The authors would like to acknowledge to University Malaysia Pahang for the financial support under UMP Research Grand RDU 1403156.

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