Enhancement of engine performance with high blended diesel-biodiesel fuel using iso-butanol additive

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Abstract. Biodiesel is one of the most common and familiar among the alternative fuels in many applications. It’s environment friendly, biodegradable as well as renewable source, to meet the future energy crises. Though blending of biodiesel with mineral diesel are suggested to operate diesel engine, it is approved as a commercial fuel at low blending ratios less than 30%. Fuel additives are the most viable option to implement the utilization of biodiesel at high bending ratio with diesel to operate un-modified diesel engine. Investigation of blended biodiesel-diesel fuel (B40) properties and engine performance with iso-butanol additives is conducted in this study at 5% and 10% additive ratio. The study results reveal that the viscosity of blended fuel is the highest which decrease with increasing additive ratio in the blend with better viscosity for B40IB10 compared to diesel fuel. On the other hand, the heating value of blended fuel is lower than that of mineral diesel and decreases with increasing additive ratio in the blend. Introducing iso-butanol additive with the blend at 5% results in significant increase in brake power compared to that of blended fuel B40. Further increase in iso-butanol additive to 10% leads to increase brake specific fuel consumption and brake thermal efficiency in which the higher value obtained. Engine test results show that introducing iso-butanol additive with the blended fuel B40 at 5% (B40IB5) can be suggested for better engine performance at high thermal efficiency.

Keywords: Biodiesel, Blending, Iso-butanol, Diesel, Fuel properties

1. Introduction
The current energy situation alarms for a series energy crises that represents a challenge for the world development [1]. The energy consumption in the present decade depended mainly on fossil fuel and it differs from last few decades with a rapid increase in the demand [2]. Though new fossil fuel reservoirs discovered with time, this rise in the reserve does not mean that it is unlimited. The regions contain oil fields were discovered by the oil companies to get the same production low cost. However, to product the oil in the near future, it will be costly and require energy that sometimes equal to or more than the extracted energy [3].

Many alternative sources were suggested to overcome the problem of increasing energy demand to reduce the dependency on the depleted fossil fuel. Current trend of research focus on the renewable energy sources that can be sustained in the future. On the other hand, the global warming starts to engage the research to investigate the ability of providing clean energy sources. The different energy types suggested by various researchers based on the viability of this energy in the study region. Energies like solar and wind utilized efficiently adopted in some regions depending on the suitability
of the environmental conditions which various from region to another [3]. However, these sources can be used in certain applications only. Internal combustion engines are used in all walks of life and designed to operate on liquid fuel. Transportation and industry sectors are the many consumer of energy in the world and they utilize fossil fuel mainly. Liquid fuel represents the large share of fuel consumed by these sectors as they mostly depend on internal combustion engine [4].

Biodiesel fuel is the most viable and suitable alternative for diesel fuel due to their comparable properties [5]. This type of fuel can be produce from different crops and animal fats which can be considered ad a renewable source of fuel [6,7]. The abundant sources of biodiesel are a crucial determination of their utilization over a wide range of applications. However, the variations in some properties need to be converged with in the required standard specifications before adoption for operating un-modified diesel engine [8]. Many methods suggested enhance the properties of biodiesel to meet the required specifications. Some researchers suggest developing various techniques for high viscosity fuel injection which need for engine modification and utilization of some accessories parts [9,10]. However, this method non-preferred due to the huge existing number of engines that need to modifies which mean extra [11]. Though blending of biodiesel with mineral diesel are suggested to operate diesel engine, it is approved as a commercial fuel at low blending ratios up to 20% [12]. Fuel additives are the most viable option to implement the utilization of biodiesel at high blending ratio with diesel to operate un-modified diesel engine [13,14].

In this study, investigation of blended biodiesel-diesel fuel (B40) properties with iso-butanol additives is conducted at 5% and 10% additive ratio, the measured properties include viscosity, density and heating value. Engine test was essential to evaluate fuel blend performance with increasing additive ratio. Same engine setting was adopted to test the different fuel samples for comparing the obtained results.

2. Methodology

Tested biodiesel fuel was provided by commercial suppliers from biodiesel refinery, diesel fuel was provided by local gas station. Iso-butanol additive was supplies by chemical company and kept in the storage under suitable conditions as specified by the instruction manual. Fuel preparation was conducted in the chemical lab under controlled environmental conditions. Blend of biodiesel-diesel fuel B40 prepared based on volume by adding the two fuels together and maxing continuously for 20 minutes using magnetic stirrer shown in figure 1 to ensure homogenous blend. After that iso-butanol added to the blend at the desired ratio while stirring for additional 20 minutes; then the final fuel mixture stored for 24 hours in the lab before conducting any test. Fuel properties test were performed according to the ASTM standard method test procedures. The viscosity has been measured using viscosity bath shown in figure 2 according to ASTM D445 standard method procedures. Fuel density has been measured using density meter shown in figure 3 according to ASTM D1298 standard method procedures. The calorific value has been measured using oxygen bomb calorimeter model 6772 shown in figure 4.

![Figure 1. Magnetic stirrer.](image1)

![Figure 2. Viscosity bath.](image2)
Engine test was conducted using a cylinder water-cooled Mitsubishi diesel engine with a cylinder displacement of 1.998 dm³ and a 22.4 to 1 compression ratio with a bore to stroke ratio of 0.89. The engine is connected to an eddy current dynamometer controlled by a dynalec controller to measure the torque and speed of the engine. Engine test was conducted at constant 2500 rpm engine speed and half load.

3. Results and discussion

Fuel property is an important indicator for the suitability of certain fuel for operating diesel engines. Standard diesel specifications are indicated by the ASTM D975 fuel standard which applied to blended fuel up to 5% biodiesel ratio with diesel [15,16]. Blended fuel up to 20% biodiesel has been approved as a commercial fuel for un-modified diesel engine by the ASTM D7467 standard fuel specifications [17]. Pure biodiesel has been specified by the ASTM D6751 which required some modification for the engine in order to be available for utilization [18,19]. Fuel viscosity is an important indicator for fuel spray formation which influences directly the combustion process [20]. Figure 5 presents the variation of fuel viscosity with increasing iso-butanol ratio compared to that of mineral diesel. It is obvious that the viscosity of blended fuel is the highest which decreases with increasing additive ratio in the blend with better viscosity for B40IB10 compared to diesel fuel. Same trend observed for density with increasing iso-butanol ratio compared to that of mineral diesel as shown in figure 6. It is obvious that the density of blended fuel is the highest which decreases with increasing additive ratio in the blend with better viscosity for B40IB10 compared to diesel fuel. On the other hand, it is observed that the heating value of blended fuel is lower than that of mineral diesel and decreases with increasing additive ratio in the blend due to the lower heating value of additive as shown in figure 7. The lower value obtained for blended fuel B40IB10.
Figure 5. Variation of viscosity with iso-butanol additive.

Figure 6. Variation of density with iso-butanol additive.
Figure 7. Variation of Heating value with iso-butanol additive.

Engine test is an essential indicator to evaluate fuel quality and suitability to operate diesel engine. The variation of alternative fuel property may leads to deterioration of engine performance due to inefficient fuel combustion [21,22]. Engine test was conducted at constant 2500 rpm engine speed in which the maximum power achieved and constant half load conditions. Figure 8 presents the variation of brake power with iso-butanol additive compared to diesel fuel. It is obvious that higher engine brake power obtained with mineral diesel which decreased by about 3% when using blended fuel B40. Introducing iso-butanol additive with the blend at 5% results in significant increase in brake power compared to that of blended fuel B40. However, further increase in iso-butanol additive to 10% lead to deterioration in obtained brake power. This behaviour may be attributed to two conflicted parameters that include the fuel viscosity which improved with increasing additive ratio and the decrease in heating value [23,24].

Figure 9 presents the variation of brake specific fuel consumption (BSFC) with iso-butanol additive compared to diesel fuel. It is obvious that lower BSFC obtained with mineral diesel which increased by about 2.7% when using blended fuel B40. Introducing iso-butanol additive with the blend at 5% additive ratio results in a slight increase in BSFC compared to that of blended fuel B40. Further increase in iso-butanol additive to 10% leads to increase BSFC in which the higher value obtained. This behaviour may be attributed to decrease in hating value with increasing additive ratio [4,25].

Brake thermal efficiency (BTE) is the most significant indicator for evaluating the engine fuel conversion efficiency. Figure 10 presents the brake thermal efficiency for different investigated fuel samples. It is observed that the BTE increases with introducing biodiesel blend. Further increase is achieved with introducing iso-butanol additive and the maximum value obtained for B40IB10. This trend of increase may attributed to the high oxygen content of biodiesel fuel and iso-butanol additive compared to mineral diesel which can improve the fuel mixture combustion process [26,27].
Figure 8. Variation of brake power with iso-butanol additive.

Figure 9. Variation of BSFC with iso-butanol additive.
4. Conclusion
In this study, investigation of blended biodiesel-diesel fuel (B40) properties and engine performance with iso-butanol additives is conducted at 5% and 10% additive ratio. The property test results show that the viscosity of blended fuel B40 is the highest which decreases with increasing additive ratio in the blend with better viscosity for B40IB10 compared to diesel fuel. On the other hand, it is observed that the heating value of blended fuel is lower than that of mineral diesel and decreases with increasing additive ratio in the blend and the lower value obtained for blended fuel B40IB10. Engine test is an essential indicator to evaluate fuel quality and suitability to operate diesel engine. The variation of alternative fuel property may lead to deterioration of engine performance due to inefficient fuel combustion. Engine test results show that introducing iso-butanol additive with the blend at 5% results in a significant increase in brake power compared to that of blended fuel B40. Lower brake specific fuel consumption obtained with mineral diesel which increased by introducing iso-butanol additive with the blend. Moreover, the brake thermal efficiency increases with introducing iso-butanol additive in the blend. Finally, 5% iso-butanol additive can be suggested with blended fuel B40IB5 for better engine performance at high thermal efficiency.

5. References
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