Enhancement of Gasoline Fuel Quality with Commercial Additives to Improve Engine Performance

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Abstract: In this study, a comparison was made to evaluate fuel properties and engine performance when using local gasoline fuel MU0 with two types of commercial fuel optimizer. MU1 (1/200 addition ratio of commercial additive U1 with local gasoline MU0), and MU2 (1/100 addition ratio of commercial additive U2 with local gasoline MU0) was investigated in addition to commercial enhanced gasoline MU3. Local gasoline MU0 has been adopted as a threshold for comparison. Performance tests conducted in a single-cylinder four stroke spark-ignition engine using fuel samples (MU0, MU1, MU2, MU3) at engine speed range from 1200 to 2800 rpm with increment of 400 rpm and open throttle valve 100% (WOT). The results showed an increased octane number and viscosity of fuel MU1 by about (3.49%, 16.92%) respectively, and reduction in the heating value by about 19.4%, with addition U1. Increase heating value and viscosity of fuel MU2 by about (1.68%, 22.31%), with addition U2. As well as, increase brake power by about (4%, 16%) at 2800 rpm with MU2 and MU3 respectively compared to local gasoline MU0. In addition, brake specific fuel consumption reduced with fuel MU3 and increased with (MU1, MU2). The brake thermal efficiency was enhanced with fuel MU1 and MU3 and the better improvement obtained for MU1 by about 22.47% at 2400 rpm.

Keywords: Octane number, Fuel optimizer, Gasoline engine

1. Introduction:
Internal combustion engines are the most widely used means of energy production in various fields of life. Gasoline engines have certain characteristics that encourage their utilization in some sectors such as the transport sector, especially vehicles engine that are characterized by high capacity to accelerate in a relatively short time [1–4]. The first half of the twentieth century implemented the use of low-octane fuels to power gasoline engines because low compression ratio of engines. However, the current design required the implementation of high octane number to obtain the desirable high efficiency. (Douihit et al. 1988) [5] reported that, the octane number of fuels increases with the addition of 15% MTBE. The addition of ethanol with different volume ratios to gasoline increases the octane number and reduces the heating value of fuel [6–8], as well as, the addition of ethanol to 10% increase raid vapor pressure for fuel (RVP) and decreases with an increase in the ratio of ethanol more than 10%. Da Silva et al. [9] study the effect of addition of oxygenates (ethanol – MTBE - ETBE) and non oxygenates (iso-octane - toluene) on RON, RVP for two types of gasoline differentiated by the chemical composition produced locally in Brazil (A & B) at addition rates of 5%, 15%, 20% and 25%. The results showed an increase in RVP when ethanol and MTBE were added, and decreased with other additives except ETBE which reduces RVP for gasoline (A) and slightly increases gasoline (B). In addition, the octane number increases with all additives. Porpatham et al. [10] investigated the
effect of methane concentration in biogas on fuel properties by reducing CO2 content in biogas from 41% to 30% and 20%. Their results showed an increase in heating value by 68.3% with a reduction of CO2 concentration to 20%. Sheet [11] study the Effect of using Octane Optimizer (R3) locally produced in the Doura refinery on fuel characteristics. Addition rates of 2.5 -15 by vol.% was showed an increase in the octane rate, reduce the gum content, heating value and increase sulfur content in the fuel. Ertan Alptekin [12] investigated the effect of G39 on fuel properties. The addition of Solketal to gasoline improves the octane rate and also reduces the composition of gum in gasoline. Yusaf et al. [13] conducted a theoretical and experimental investigation on adding E5, E10, E15 and E20 on the performance of the four - cylinder SI engine. The results showed an increase in brake power, brake thermal efficiency and lower brake specific fuel consumption with the addition of ethanol compared to pure gasoline. Nazzal [14] found an increase in brake power by 21.6%, reduced brake specific fuel consumption by 10% and increased brake thermal efficiency by 17% with the addition of 12% ethanol to the gasoline. Ashraf Elfasakhany [15] conducted an experimental investigation on additive effect (E3, E7, E10) on the performance of the single - cylinder SI engine at a speed of 2600 - 3400 rpm. The results showed an increased brake power, torque, volumetric efficiency, exhaust gas temperature, pressure inside cylinder and decreased brake specific fuel consumption. The E10 gave the best performance of the engine at different engine speeds. The reviewed studies show that various additives have been implemented by different researchers, among these additives the local commercial additives that can adopt based on the locally produced fuel requirements. The objective of this study is to investigate the effect of commercial fuel utilization to enhance fuel quality and engine performance at wide range of engine operation conditions.

2. Experimental setup:
2.1 Test fuels:
In this study, four different fuels were used for property analysis engine performance tests. Local gasoline fuel was marked as MU0 for reference, and (1/200) added ratio of commercial fuel optimizer by volume to local gasoline fuel were named as MU1, and (1/100) added ratio of commercial fuel optimizer by volume to local gasoline fuel were named as MU2, in addition to commercial enhanced gasoline fuel named MU3, as shows in Table 1.

| Fuel samples | Addition ratio | Type of commercial fuel optimizer | Description |
|--------------|----------------|-----------------------------------|-------------|
| MU0          | ----           | ----                              | 100% local gasoline. |
| MU1          | 1/200 vol.     | U1                                | 1 vol. U1+200 vol. local gasoline. |
| MU2          | 1/100 vol.     | U2                                | 1 vol. U2+100 vol. local gasoline. |
| MU3          | ----           | ----                              | 100% commercial enhanced gasoline. |

2.2 Engine test:
Experimental tests were carried out on a small modified four-stroke spark ignition engine; type (Robin EH17) compression ratio and spark timing are constant. Table 2 shows the specifications of the engine used to perform the tests in this research.

| Parameters                  | Value          |
|-----------------------------|----------------|
| Displacement                | 172 cm²        |
| Bore × stroke               | 67 mm × 49 mm  |
| Configuration               | four stroke, spark-ignition, single cylinder |
| Connecting rod length       | 85 mm          |
| Fuel                        | gasoline       |
| Compression ratio           | 8.5:1          |
The engine loading system consists of a hydraulic dynamometer installed on a standard test base. The engine is installed on it and the engine is connected to the hydraulic dynamometer via the end of the crank shaft out of the engine. The maximum power of the hydraulic dynamometer is 7.5 kW at 7000 rpm. Which applies the load according to the water flow rate and the water level inside its casing. It is a simple and efficient method that the use of a hydraulic dynamometer has the advantage of not requiring a huge electrical supply, as well as the engine energy is dissipated in the form of heat in the water used. The amount of water supply required for the hydraulic dynamometer size is determined as a minimum of 5 L / min at 1 bar. The electronic load cell, type S with a maximum load capacity of 15 N.m, is adjusted along with the power gauge.

3. Results and discussion.
We present the results of testing the physical and chemical properties (octane number RON, heating value, density and viscosity) and the results of experimental tests of engine performance (Brake power BP, Brake specific fuel consumption BSFC and Brake thermal efficiency BTE). The study conducted using local gasoline fuel with two types of commercial fuel optimizer and commercial enhanced gasoline (MU0, MU1, MU2, MU3) in a single-cylinder, four-stroke ignition engine (Robin EH17) operating at engine speeds ranging from 1200 to 2800 rpm with an increment of 400 rpm and 100% throttle valve opening (WOT). Engine working conditions are maintained same in almost all experiments, such as environment temperature ambient, pressure and humidity.

3.1 Fuel property analysis
The characteristics of the fuel used in the operation of internal combustion engines are one of the most important determinants in terms of efficiency and quality of combustion [16–21]. The physical and chemical properties measured and discussed in this paper included; octane number, calorific value, density and viscosity. These properties have been studied for the four fuel samples (gasoline MU1 prepared from the addition of commercial fuel optimizer U1 on local gasoline MU0 by (1/200), (gasoline MU2 prepared from the addition of commercial fuel optimizer U2 on local gasoline MU0 by (1/100). Properties were also studied for commercial enhanced gasoline MU3, in addition to local gasoline MU0 as a comparative criterion for the rest of the fuel samples that have been studied. The physical and chemical properties of MU0, MU1, MU2, MU3 have been examined in Kirkuk oil depot laboratory and petroleum research and development center.

3.1.1 Octane number RON:
The octane number is a measure of gasoline fuel resistance to knock in spark ignition engines. The higher the octane RON of gasoline, the greater the ability of the fuel to resist spontaneous ignition during compression and before spark ignition [22,23]. Higher compression means higher temperature and pressure that can be achieved within the engine cylinder and translates into higher engine power. Figure 1, shows the results of the examination of the research octane number of fuel samples (MU0, MU1, MU2, MU3). Note that the octane number of commercial enhanced gasoline MU3 is higher than local gasoline MU0, while the octane number of fuel MU3 (RON 92.9) and fuel MU0 was 86. The increase in the octane number of commercial enhanced gasoline MU3 was 8.02% compared with local gasoline MU0.

In addition, it is observed that the effect of adding commercial fuel optimizer was noticeable on the fuel octane number. The octane number RON of fuel MU1 increased from RON 86 when the commercial fuel optimizer U1 added to local gasoline MU0 to RON 89, and the addition of the commercial fuel optimizer U2 reduced the octane number of fuel MU2 to RON 85.3 compared with local gasoline MU0. The octane number RON for fuel MU1 increased with the addition of the commercial gasoline optimizer U1 by about 3.49% and the addition of the optimizer U2 reduces the octane number by about 0.8% for fuel MU2 compared with the local gasoline MU0.
3.1.2 Heating value:
Heating value is the amount of energy that one kilogram of fuel generates when it is fully burned. It measured in MJ / kg unit by using oxygen bomb calorimeter. The test results shown in Figure 2 shows that the heating value of local gasoline MU0 was 44.598 MJ / kg while the heating value of commercial enhanced gasoline MU3 was 43.781 MJ / kg, which is lower by about 1.83% than local gasoline MU0.

The results of the laboratory test showed that the heating value was significantly reduced to the 35.948 MJ / kg for fuel MU1 when the commercial fuel optimizer U1 added to local gasoline and found to be lower by about 19.4% than local gasoline MU0. The addition of the commercial fuel optimizer U2 increases the heating value to 45.347 MJ / kg and improved by about 1.68% compared with local gasoline MU0.

3.1.3 Density:
Density is the ratio between the mass and volume of fuel and is a physical characteristic of the fuel that affects the fuel economy of the engine by affecting the process of equivalent combustion and high density increases the energy density of the fuel [24–30]. Affect fuel spray quality and combustion efficiency because the engine's fuel processing systems are volume-based, and therefore, power out of
the engine is affected by the density difference due to the difference in the mass of fuel supplied to the engine [31–37]. Figure 3 shows the fuel density for MU0, MU1, MU2 and MU3 found to be 727, 723, 724, 747 kg/m³ respectively. The density of fuel MU3 is higher by about 2.75% than local gasoline MU0. It is obvious that the addition of commercial fuel optimizer had a slight effect on density.

![Figure 3. Density (kg/m³)](image)

**3.1.4 Viscosity:**
Viscosity is a measure of internal friction or fuel resistance to flow, it is a very important property of fuel, as it affects the operation processing of fuel system equipment [38–43]. Figure 4 shows the results of the viscosity of fuel samples MU0, MU1, MU2, MU3 found to be 0.26, 0.304, 0.318, 0.308 mm²/sec respectively. The viscosity of commercial enhanced gasoline MU3 is found to be higher by about 18.46% compared with local gasoline MU0. As well as the effect of adding commercial fuel optimizer is obvious to be significant on the viscosity of the fuel. The viscosity of local gasoline MU0 is 0.26 mm²/sec increased with the addition of the commercial optimizer U1 to 0.304 mm²/sec, at 16.92% increment percentage. Furthermore, the viscosity of the fuel MU2 increased to 0.318 mm²/sec, when the commercial fuel optimizer U2 was added at 2.31% increment percentage.

![Figure 4. Viscosity \( \nu \) (mm²/s)](image)
3.2 Brake torque (BT) and brake power (Bp):
Engine brake power (BP) can be calculated based on the engine's brake torque per speed. Figure 5 shows the brake power of the experimental engine tests for the used fuel samples (MU1, MU2 and MU3) and comparing the results with the results of the experimental tests for local gasoline fuel MU0 at the same operating conditions of the engine. It observes that increasing brake power is obtained as the engine speed increased. However, the brake power of local gasoline MU0 is higher than that of fuel MU3 at low speed, especially at 1200 and 1600 rpm, and higher than fuel MU1 at all engine speeds. This is due to the low calorific value of fuel MU1 and MU3) compared with the heating value of local gasoline MU0, (35.948, 43.781, 44.598 MJ / kg for MU1 & MU3 and MU0 fuels respectively) [44–49] as shown in Figure 2. Therefore, the brake power of MU0 has increased. It is important to show that, the fuel MU1 and MU3 have a higher octane number (RON 89 and RON 92.9 respectively) compared with local gasoline MU0 (RON 86), as shown in Figure 1, which results in better performance. However, the calorific value of fuel MU1 and MU3 is lower than the calorific value of local gasoline MU0, which dominates engine performance more than the octane number of fuel when the engine is running.

The brake power of MU1 and MU3 at 1200 rpm was lower by about (13.04%, 4.35%) respectively, and at 1600 rpm is lower by about (7.41%, 1.85%) respectively, compared to fuel. MU0. At the high speed of the engine (2400, 2800 rpm) the brake power of MU3 is increased compared to local gasoline MU0, due to the octane number of fuel MU3, it's higher than fuel MU0. This is consistent with the results obtained from previous studies [50,51]. The increase in brake power of MU3 at 2400 rpm found to be 5.17% and at speed 2800 rpm 16%, compared to local gasoline MU0. The best improvement in brake power achieved at speed 2800 rpm with MU3 fuel by 16%.

The effect of adding commercial fuel optimiser was also evident. At 1200 rpm, the engine brake power of MU2 increased by about 2.17% compared to the local gasoline MU0. This is attributed to the high calorific value of fuel MU2 compared with fuel MU0 (45.347, 44.598 MJ / kg for MU2 fuel and MU0 fuel respectively), as shown in Figure 2. At the speed of 2000, 2400 and 2800 rpm, the engine brake power of MU2 increased by about 1.79%, 1.72%, 4.00% respectively, compared with local gasoline MU0.

![Figure 5. Brake power against engine speed.](image-url)
3.3 Brake specific fuel consumption (BSFC):
Variance in brake specific fuel consumption BSFC of engine fuel samples relative to different engine speed at wide open throttle (WOT) shown in Figure 6. It can be seen that the ratio of the brake specific fuel consumption of all fuels used in the experimental engine tests is high at low speed. This trend due to the fact that when engine work at low speed the effect of weak combustion and cooling is strong, which leads to a high level of brake specific fuel consumption (BSFC) for all fuels. As the engine speed increases, the BSFC decreases to a minimum at 2000 rpm, due to a gradual improvement in the combustion process, thus increasing the overall energy utilization. The BSFC then begins to increase gradually as the engine speed increases for all tested fuel samples.

As shown in Figure 6, the lower BSFC achieved for MU3 at all engine speeds compared to MU0. Brake specific fuel consumption for MU3 at speed 1200, 2000 and 2800 rpm decreases by about 0.4, 0.52 and 2.46%, respectively compared with local gasoline MU0. This improvement in brake specific fuel consumption due to the increase in energy density [52], as well as the high octane number of fuel MU3 [50,51]. It can be seen from Figure 6, that the effect of adding commercial fuel optimizer on the brake specific fuel consumption was evident. Brake specific fuel consumption with MU1 and MU2 has increased at all engine speed compared with that of MU0.

The increase in brake specific fuel consumption BSFC at engine speed 1200 rpm for fuel MU1 and MU2 found by about 11.73%, 3.29% respectively. This is attributable to the increased viscosity of fuel with the addition of commercial fuel optimizer as shown in Figure 4. At the same time, BSFC at 2000 rpm increased by about 10.73, 0.88% respectively, while BSFC increased at 2800 rpm by about 12.47, 0.18%, respectively compared with local gasoline MU0.

![Figure 6. Brake specific fuel consumption against engine speed.](image)

3.4 Brake thermal efficiency (BTE):
Brake thermal efficiency is the ratio of the brake power produced by the engine to the total thermal energy in the fuel. It is a measure of the evaluation of engine operation using test fuel. One of the performance factors used to assess the engine's ability to convert heat energy from fuel to mechanical energy is the best estimate of engine performance from fuel consumption of different fuels used in experimental tests, as well as the calorific value. Figure 7 shows that the brake thermal efficiency (BTE) increased for MU1 and MU3 fuel per engine speeds compared with local gasoline MU0. The BTE of fuel MU1 at engine speed 1200, 1600, 2000, 2400 and 2800 rpm increased by about 11.04%, 13.15%, 12.04%, 22.47% and 10.31% respectively, compared to local gasoline MU0.
At the same time, we notice that the brake thermal efficiency increases with the use of MU3 fuel in the test engine at a speed of 1200, 1600, 2000, 2400 and 2800 by about 2.27%, 3.53%, 2.39%, 3.06% and 4.44% respectively, compared with local fuel MU0. The increase in brake thermal efficiency obtained when using fuel MU1 and MU3 in the engine is due to higher octane number compared to MU0 fuel. Reduction in brake thermal efficiency compared to local fuel MU0 achieved when using MU2 fuel in the engine at speed of 1200, 1600, 2000, 2400 and 2800 rpm by about 4.79%, 1.91%, 2.51%, 1.84% and 1.83% respectively.

![Figure 7. Brake thermal efficiency against engine speed.](image-url)

Note that the BTE of fuel MU3 is higher than the efficiency of MU0, the brake thermal efficiency of MU1 is higher than that of MU0 and MU3 with best brake thermal efficiency for MU1 under the same engine operation conditions.

4. Conclusion:
In this research, experimental study of the effect of adding commercial fuel optimizer on the properties of local gasoline fuel (number of octane, heating value, density, viscosity) and engine performance (Brake power, Brake specific fuel consumption, Brake thermal efficiency). Performance tests are conducted under different operating conditions with engine speeds ranging from 1200 to 2800 rpm at an increment of 400 rpm and throttle valve opening 100% (WOT). Based on this work, the conclusion can be drawn as following:

- Increase octane number and viscosity of fuel MU1 compared to the local gasoline MU0 with added commercial fuel optimizer U1 (1/200 vol.) by about 3.49% and 16.92%, respectively, and slightly effect on the fuel density and reduces the heating value of fuel MU1 by about 19.4%.
- Increase heating value and viscosity of fuel MU2 compared to the local gasoline MU0 with added commercial fuel optimizer U2 (1/100 vol.) by about 1.68% and 22.31%, respectively, and slightly effect on the octane number and density of fuel MU2.
- Increases brake power of fuel MU2 by about 4% at 2800 rpm with added commercial fuel optimizer U2 (1/100 vol.) compared to the local gasoline MU0.
- Decrease brake power of fuel MU1 by about 2% at 2800 rpm with added commercial fuel optimizer U1 (1/200 vol.) compared to the local gasoline MU0.
- Increases brake power of fuel MU3 by about 16% at 2800 rpm compared to the local gasoline MU0.
• Decrease BSFC of fuel MU3 by about 2.46% at 2800 rpm compared to the local gasoline MU0.
• Increase brake specific fuel consumption (BSFC) by about (12.47%, 0.18%) at 2800 rpm with the addition of the commercial fuel optimizer (U1, U2) compared to the fuel MU0.
• Increased brake thermal efficiency (BTE) with the addition of the commercial fuel optimizer MU1 by about 10.31% at 2800 rpm compared to the local gasoline MU0, and increasing with fuel commercial enhanced fuel MU3 by about (4.44%) at 2800 rpm compared to the fuel MU0.
• Decrease brake thermal efficiency (BTE) with the addition of the commercial fuel optimizer MU2 by about 1.83% at 2800 rpm compared to the local gasoline MU0.
• At low engine speed of the heating value of fuel dominant on the engine’s performance (Brake power) from the octane number of fuel, As with fuel (MU1, MU3). At high speed the octane number is more effective on engine performance.

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