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A Simulation of the Impact of Biodiesel Blends on Performance Parameters in Compression Ignition Engine

Fouad Alwan Saleh[1], Mohammed Kadhim Allawi[2*],
Murtdha S.Imran[3], Ahmed Oleiwi Samarmad[4]

[1] Mechanical Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq
[2] Technical Engineering College-Baghdad, Middle Technical University (MTU), 10001 Baghdad, Iraq
[3] Mechanical Engineering Department, Engineering College, Kerbala University, Iraq
[4] Department of Air Conditioning and Refrigeration, Faculty of Engineering, University of Warith Al-Anbiyaa, Karbala, 56001, Iraq
* Corresponding author's e-mail: mka83@mtu.edu.iq

ABSTRACT

Recently, there has been significant interest in biodiesel, since it depends on renewable resources, which is essential given the increasing depletion of fossil fuels. Using palm oil in biodiesel production is an innovative application of botanical resources in this sector. Simulation research examined how blending palm oil with Iraqi conventional diesel influences engine performance. The impact of several mixtures, consisting of different proportions (5%, 10%, 15%, and 20%) of palm oil and diesel, on engine fuel consumption, volumetric efficiency, torque, brake mean pressure, brake power, and thermal efficiency was evaluated in each case. The study found that using palm oil fuel at a mixing ratio of 20% resulted in a 4% increase in fuel consumption. Furthermore, a 3% enhancement in volumetric efficiency was also noted. Again, there was a noticeable reduction in the torque, power, and average adequate pressure levels across all diesel fuel mixing ratios compared to diesel fuel, which exhibits the highest value.

Keywords: biofuel, compression ignition, performance, LOTUS.

INTRODUCTION

In recent years, considerable global focus has been on the potential applications of compression-ignition (CI) engine biodiesel fuel (BDF) derived from vegetable oil feedstock. This attention stems from the desire to decrease the reliance on petroleum resources and substantially lessen the greenhouse gas emissions [1–5].

Preheated palm oil was utilized to fuel the diesel engine. By preheating the fuel, its viscosity was decreased, leading to improved spraying and atomization characteristics. Furthermore, the braking power, torque, exhaust contaminants, BTE, and brake-specific fuel consumption (BSFC) were comparable to diesel fuel. In [6], authors conducted trials with a (CI) engine. A mixture of palm BDF 5% palm and 95% diesel fuel (DF) served as the engine's fuel. They noticed slight brake power (BP) and torque variations between B5 and DF. It was noticed that BSFC increased as the nitrogen oxides (NO_x) emissions decreased, which occurred when the engine was fueled with B5. The amounts of carbon monoxide (CO), carbon dioxide (CO_2), and UHC released into the air were lower when a fuel blend of 5% BDF (B5) was used instead of DF [7].

The researchers examined the physio-chemical properties of palm oil and BDF blends, specifically investigating density, viscosity, and flash point. The qualities were experimentally evaluated using the ASTM test method, and a model was subsequently created to predict these properties. Their findings demonstrated a high degree of similarity between the attributes of BDF and DF. Furthermore, they successfully confirmed the accuracy of their model by comparing it to trial data from other sources, which exhibited favorable correspondence.

The study conducted by [8] examined the effects of engine efficiency on a Kirloskar engine. The study focused on the influence of different metallic fuel additives and tall petroleum methyl esters on engine performance under full load conditions. Adding metallic additives Mo and Mg did not significantly alter torque or engine power when applied to B60 biological diesel. The study examined the combustion properties of BDF mixes compared to DF, emphasizing the increasing enthusiasm for renewable resources in manufacturing BDF [9, 10, 11]. The researchers looked into what happens to the efficiency and emissions of a pickup diesel engine that runs on a mix of DF and palm BDF when multifunctional additives are added. They found that adding TiO_2 had the most significant impact on enhancing engine power compared to using pure B5 or pure diesel. The gains included a 7.78% rise in engine power and a 1.36% enhancement in torque. In [12, 13] the researchers examined how well direct injection engines worked and what were the emissions when using preheated palm oil and different oil blends with DF. The O20 blend showed the highest mechanical performance at higher compression ratios, 14.6% more efficient than DF. It also offered low exhaust gas temperatures as well as decreased the CO and hydrocarbon (HC) emissions. However, the CO_2 emissions were more significant than DF [14]. This study examined the influence of an additive on the efficiency of the CI engines powered by Malaysian palm oil BDF. Their research found that adding an additive to a BDF (B20) led to a 1.73% enhancement in brake power compared to utilizing only B20 and a 9.9% improvement when compared to using exclusively diesel fuel.

In addition, the energy derived from the fuel mixture known as “B20 + 1%” resulted in a 26% and 6% reduction in (BSFC) compared to B20 and ordinary DF, respectively. In addition, the use of “B20 + 1%” fuel resulted in a decrease in the CO, NOx, and CO_2 emissions when compared to alternative fuels [15]. More studies are needed to investigate the employment of biodiesel blends within the Lotus program, specifically as a fuel for diesel engines, notably considering their performance characteristics during combustion. The primary purpose of this study was to investigate the influence of palm oil biodiesel blends on the performance and efficiency of biofuel in comparison to Iraqi diesel, revealing insights into their effects on diesel engines.

METHODOLOGY

Engine specifications

A laboratory engine simulation was carried out using LOTUS software, based on the practical features of an engine, such as capacity, cylinder size, stroke length, and compression ratio, while strictly adhering to the technical requirements. Fuel details have been duly considered, including density, calorific value, weight, and mixing ratio. Table 1 details the engine specifications, Figure 1 visually represents the test bench engine, whereas Figure 2 is the engine simulation model schematic.

Fuel sample preparation

The samples are created by blending traditional diesel with different proportions of palm oil (5%, 10%, 15%, and 20% by volume). The palm oil underwent purification to eliminate any food residue, after which it was combined with diesel fuel at a consistent temperature of 60 °C. This process involved using KOH to separate the gum substance formed from palm oil and diesel fuel. Removing the gum material from diesel and vegetable oil combinations was essential, since it can lead to engine damage, including compression ring sticking and fuel pipeline clogging. Figure 3 displays the biodiesel samples that were obtained. The heating value, density, viscosity, and flash point temperature of fuel were assessed for each fuel using suitable instruments, and the findings are documented in Table 2.

Table 1. Engine qualifications

N	Part name	Value
1	Engine model	95310
2	Cylinder	1
3	Stroke	4
4	Bore	60 mm
5	Stroke length	42 mm
6	Compression ratio	17
7	Displacement	118 cm^3

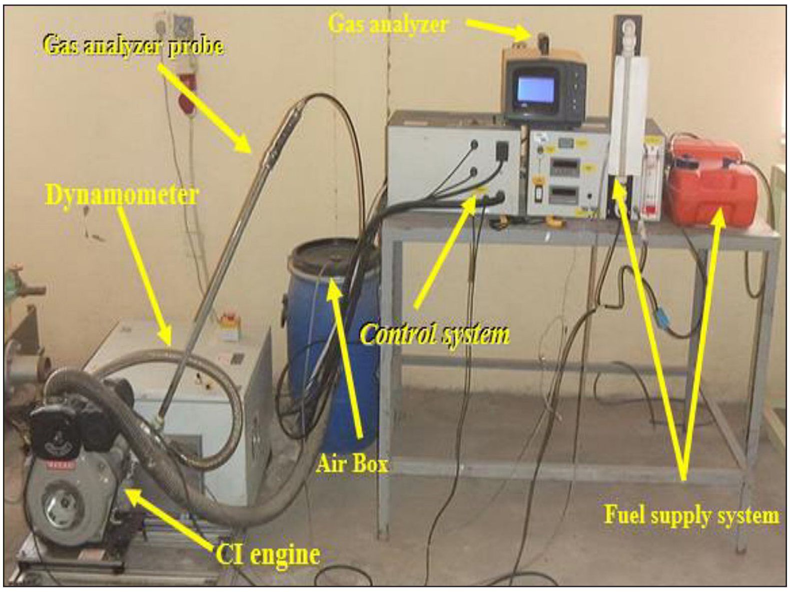

Figure 1. Combustion system examination apparatus

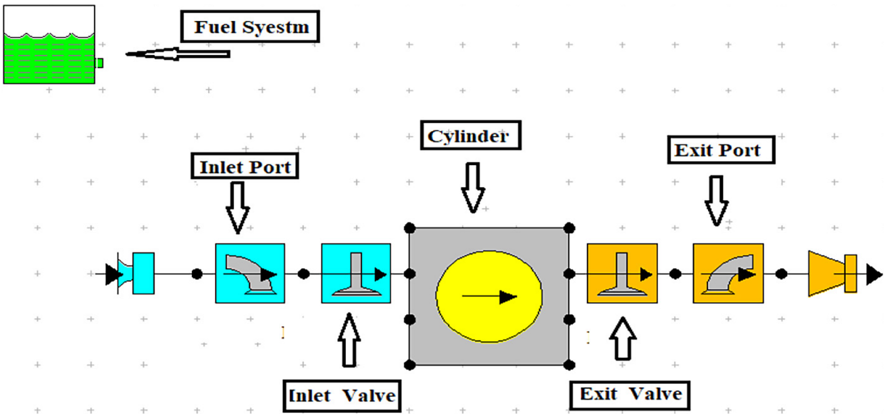

Figure 2. The engine model schematic

Table 2. Physical properties of fuels

Property	unit	Diesel	B5% palm oil	B10% palm oil	B15% palm oil	B20% palm oil
Density at 15 °C	kg/m³	856	859	864	877	882
Kinematic viscosity at 38.8 °C	mm²/s	2.82	2.92	2.98	3.2	3.7
Flash point temperature	°C	60.1	63	66	68	71
Calorific value	MJ/kg	46.515	44.105	43.52	42.980	42.503

RESULTS OF THE SIMULATION

Brake specific fuel consumption

BSFC refers to the fuel consumption rate per unit of power generated. Figure 4 demonstrates that BSFC was elevated when using BDF blends compared to DF. These findings indicate that BDF blends exhibit higher fuel consumption than DF when operating at equivalent speed levels. The occurrence can be attributed to the heightened density and reduced calorific value linked to BDF mixtures. BSFC which is in agreement with the results of [16, 17]. Nevertheless, all fuel types exhibit a consistent pattern of dropping as the speed reaches 4000 rpm.

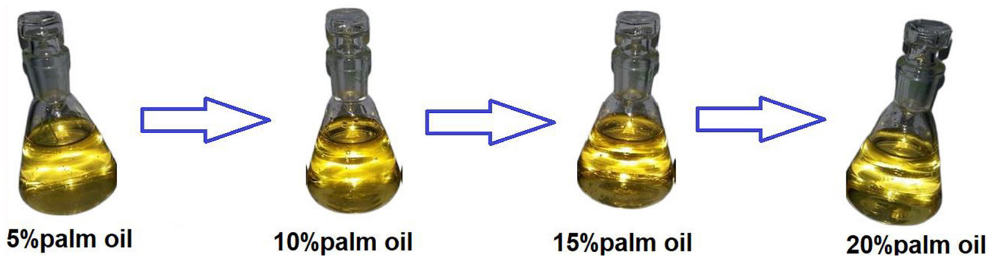

Figure 3. Fuel samples

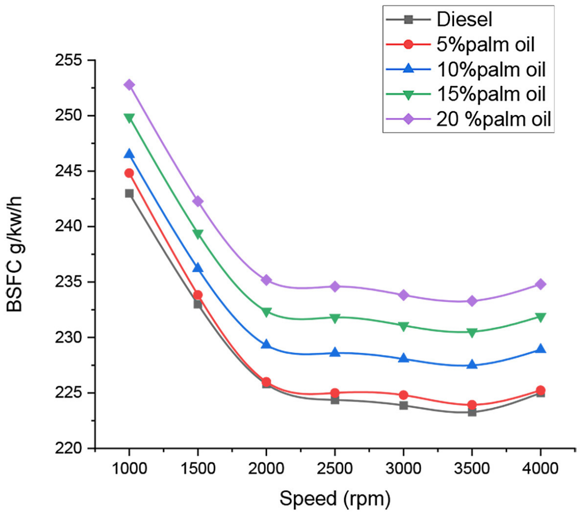

Figure 4. The relationship between BSFC usage and speed engine for different fuel blends

Brake thermal efficiency

Figure 5 depicts the variations in brake thermal efficiency (BTHE) across several BDF mixes. The BTHE measures the engine's capacity to convert the chemical energy stored in the fuel into sound mechanical energy with high efficiency. The DF and BDF blends demonstrated increased BTHE when operating at 4000 rpm. The results are consistent with those of other researchers who have looked into similar fuel mixtures, most notably the study carried out by [18]. The note is that differences in the oxygen content of the fuel cause changes in BTHE.

Torque

Figure 6 depicts the relationship between engine torque throughout the operation, explicitly comparing the torque produced by DF and BDF at different mix percentages and engine speeds. According to the study, the brake torque decreases as the BDF blend ratio rises compared to DF. The outcome aligns with the conclusions of other researchers who have investigated comparable fuel mixtures, notably the study conducted by [19].

Mean effect pressure (BMEP)

Figure 7 illustrates the relationship between the BMEP generated by DF and BDF at various blend ratios and engine velocities during the entire operation. BMEP is a theoretical constant pressure assumed to apply for equivalent work on the piston throughout its expansion stroke and the entire cycle. The velocity increase led to a noticeable increase in the mean practical pressure value. The observed conduct aligns with the conclusions reached by the researchers [20].

Volumetric efficiency

Figure 8 illustrates the relationship between engine speeds and the volumetric efficiency of biodiesel mixes. Significantly, lower engine speeds demonstrate a marked reduction in

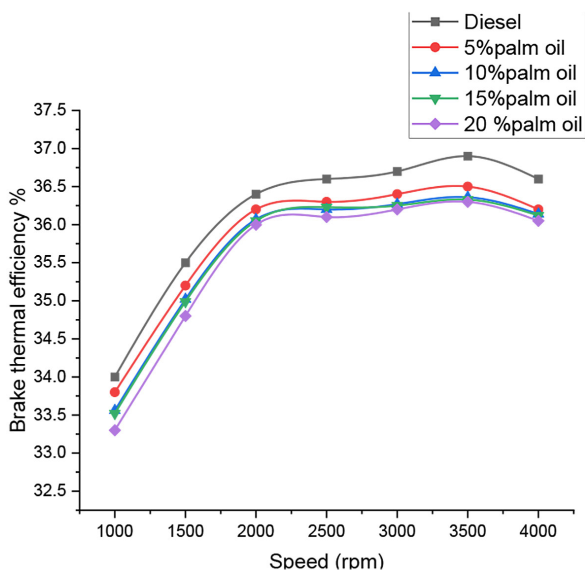

Figure 5. The relationship between BTHE and speed engine for the different blends

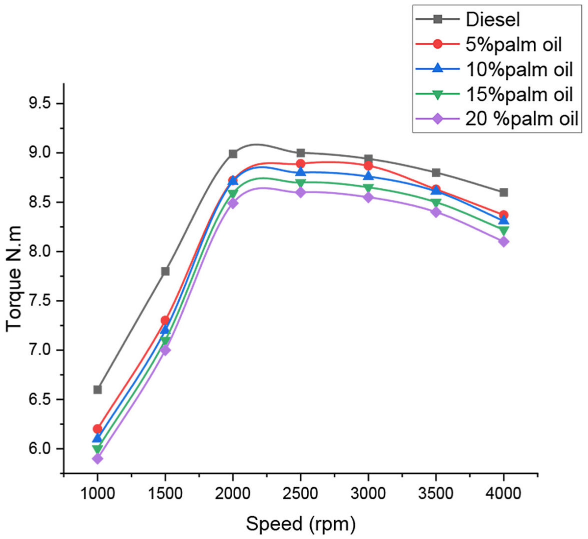

Figure 6. The relationship between speed engine and torque for different fuel blends

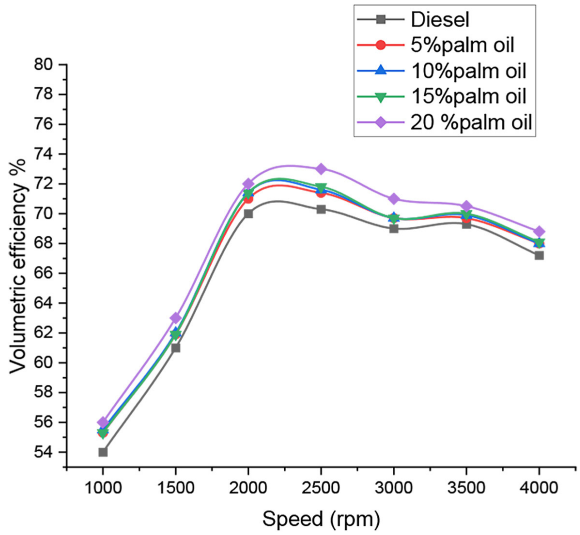

Figure 8. Volumetric efficiency at various engine speeds

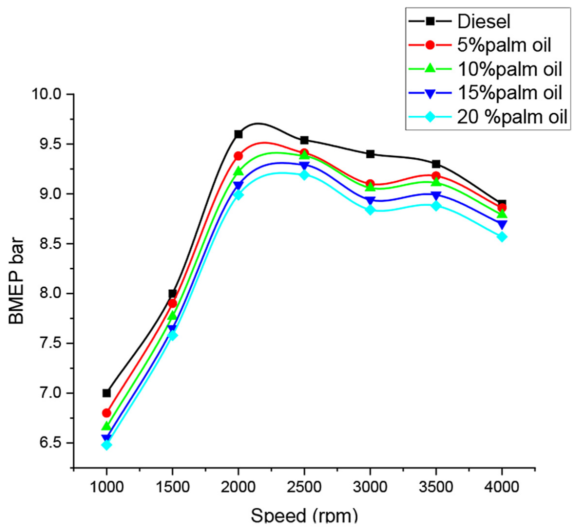

Figure 7. BMEP at various engine speeds

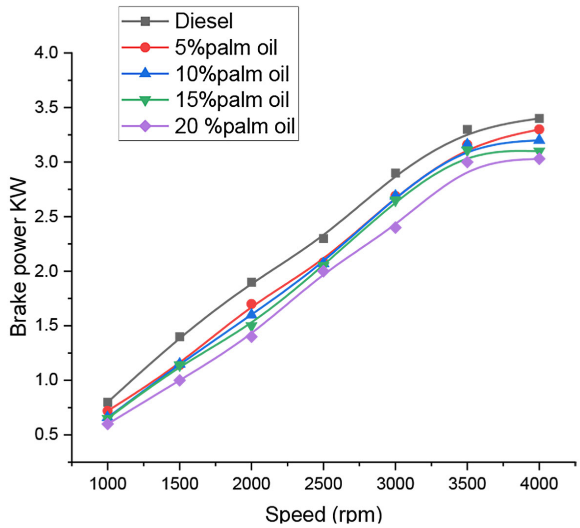

Figure 9. BP at various engine speeds

volumetric efficiency, which gradually improves as the speed increases. The maximum volumetric efficiency is achieved at a rate of 2000. The augmentation in velocity aligns with heightened ingestion of the amalgamation into the cylinders, amplifying air intake efficiency. Nevertheless, variations are detected within the range of speeds ranging from 2500 to 4000. This behavior is consistent with the findings of the researchers [21].

Brake power

Figure 9 illustrates the relationship between BP and BDF blends. Increasing the engine speed has intensified the pressure difference between the engine cylinder and the atmosphere at the beginning of the inlet stroke, resulting in a greater flow of new charge and higher energy release. In contrast, increasing the proportion of BDF in blends leads to a reduction in BP. The output torque had a marginal decline as the blending ratio rose, attributable to the elevated viscosity of the palm oil BDF. The palm oil BDF has a lower calorific value compared to diesel fuel. The density of BDF exceeds that of DF. Consequently, more fuel must be consumed to offset the decreased energy content compared to DF [22, 23, 24] .

CONCLUSIONS

The research investigated the effects of including palm oil BDF blends on the operational efficiency of diesel engines. The results indicate that these mixtures demonstrate increased fuel consumption, and greater volumetric utilization in comparison to DF. Nevertheless, despite these attributes, the use of palm oil BDF blends results in reduced measurements such as brake torque, BMEP, BP, torque, and BTHE when compared to the use of DF. The variations in combustion qualities, energy content, or chemical features of the biodiesel mixes could account for this phenomenon in terms of changeable performance.

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