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# The Effect of Using Waste Corn Oil on Compression Ignition Engine Performance

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**Abstract**

Biodiesel is one of the alternative fuels types which is renewable, and it is represented as a friend for the environment. This fuel can be used in diesel engines without or with slight adjustments. In the current study, an experimental study was performed on four strokes, single cylinder diesel engine to detect the effect of using waste corn oil on compression ignition engine performance.

The waste corn oil was mixed with the traditional diesel fuel into percent of (5%, 10%, 15%, 20%) by volume. Different engine speeds were used in this work from (1400 to 3000) rpm into 300-rpm increment.

The experimental consequences displayed that the waste cooking oil and conventional diesel blend rise the brake specific fuel consumption up to (11.4%*)*. The results revealed that the use these blends reduced the exhaust gas emissions nearly by ( 25.625%) of CO, (32.2%) of HC, but increasing $CO_2$ and $NO_X$ emissions by (*41.20* %,*29.92%*) respectively.

**Keywords:** Combustion, Biodiesel, Compression Ignition.

## INTRODUCTION

The lack of conventional fuels in front of increased fuel demand, increase the level of combustion emissions by creating pollutants and increasing traditional fuels price that all make using biofuel in the combustion field more promising. One of the potential alternative fuel is biodiesel to face the above the requirements. Therefore, the practical alternative for compression-ignition engines is biodiesel [1]. Abu-Qudais studied the act of single cylinder diesel engine by investigating the effect of using methanol diesel blend and methanol fumigation. The best ethanol fumigation percentage is 20% by volume. The practical results manifest the increase in thermal efficiency into percent of 7.5% and reduce the soot emission by 51%.The best diesel ethanol blend is 15% by volume causes a reduction in soot emission by 32% and increase in brake thermal efficiency by 3.6% [2].

Mustafa investigated the effect of using biodiesel prepared from the animal fat base and soya ben oil on compression ignition engine emissions and performance. The experimental results show that the biodiesel fuel decreased the emissions of carbon monoxide and unburned hydrocarbon and gave better engine performance [3]. Kalligeros substituted biodiesel produced from olive oil and sunflower oil with marine diesel. The experimental results showed that both types of biodiesels improved emission regarding particulate matter, carbon monoxide, nitrogen oxide and hydrocarbon, with a minor rise of the volumetric fuel consumption[4].

John Britt investigated that the biodiesel emissions are lower in carbon dioxide, sulphur dioxide, carbon monoxide, and other emissions than conventional diesel emissions. In fact, the quantity of carbon dioxide emitted into the air by combustion is the equal amount that absorbed by growing corn oil or soybeans [5]. Doradoa examined the influence of using dual fuel on exhaust emissions and compression ignition engine performance. The experimental work was accomplished by using direct ignition Perkins compression ignition engine at steady state operating condition and operated with waste olive oil. The experimental outcomes showed a reduction in emissions of CO2 (by 8.6%, CO (by 58.9%), SO2 (by 57.7%), and NO (by 37.5%). Moreover, it showed a rise in emissions of $NO_2$ (by 81%, excluding a situation which has a minor decrease)[6].

Etinkaya studied the influence of using waste cooking oil as a biofuel on diesel engine performance experimentally. The biofuel prepared from waste sunflower oil and hazelnut soap stock mixture. The experimental results show that the CO emissions from biofuel burning are higher at low speed and full load but its lower at high speed than those results when used conventional diesel as a fuel. The biofuel combustion causes a reduction in $SO_2$ emissions but increasing in $CO_2$ and $NO_X$ productions[7].

Rao investigated the consequence of using waste cooking oil on compression ignition engine performance and burning characteristics (ignition delay, heat release, peak pressure). The experimental consequences show that when using cooking oil methyl ester (WCO) records 51.481 J/°CA at burning angle of 88º bTDC while for diesel at burning angle 68º bTDC, was recorded of 51.481 J/°CA. Moreover, the practical effects explained that the heat of combustion rate declines with an increase in the fraction of waste cooking oil in the biofuel[8].

Sureshkumara studied the possibility of a fueled old model of a diesel engine with methyl ester and its mixtures with diesel on compression ignition engine performance. The measuring parameter in this experimental work is brake specific energy consumption, engine emissions and brake specific fuel consumption; the practical effects demonstrate that the biodiesel contains 40% by volume of PPME improved engine act and decrease engine emissions[9].

Hamdan examined the influence of using diesel–ethanol and diesel–ether mixtures on compression ignition engine performance. The volumetric percentage of ethanol or ether in conventional diesel was varied from with from 5%, to 15% by volume in 5% increments. The engine speed was varied from1000 to 4000 rpm. The engine characteristics which are measured in this experimental work are engine brake mean effective pressure, thermal efficiency, brake power and specific fuel consumption. Consequences illustrate that the higher value of thermal efficiency occurs when using blend contained 15% of ethanol or ether. It was noticed that both the thermal efficiency and engine specific fuel consumption rise with the ratio of alcohol in the fuel combination. While the power decline with the quantity of alcohol the fuel blends[10].

Kandasamy investigates experimentally the effectiveness features of a single cylinder diesel engine using rice bran oil combined with diesel fuel. The engine powered by using a mixture of vegetable oil and conventional diesel. The volumetric of vegetable oil mixing with diesel is 20%, 40%,60%,80%. The results related to the conventional diesel. The blend was preheated before injected into the combustion chamber. The results show improvement in engine thermal efficiency and whole performance of the engine when preheating the fuel. They get the maximum engine efficiency when using blend contained 60% of pun gam oil and 40% conventional diesel or 40% rice bran oil and 60% conventional diesel[11].

Enweremadu Studies and validate that waste cooking oil, and its mixtures have a short ignition delay period. The biofuel prepared from conventional diesel and waste cooking oil. This experimental work displays that the delay period decreased with a rise in vegetable oil percent in oil diesel blend[12]. Nafis studied the influence of using rice bran and karanj, jatropha blends with diesel fuel in diesel engine of a single cylinder. The results of the vegetable oil and pure diesel give a like engine performance and emissions level with a rise in engine fuel consumption and engine speed because of low heating value when using biofuel. The engine running very difficult at full load when using biodiesel as a fuel because of the carbon deposit was accumulated at the engine head which caused engine knocking, erratic engine running and vibrations[13].

Kamal examined the influence of using karanj-diesel blend and diesel oil on four strokes, single cylinder, constant speed, water cooled, stationary, compression ignition engine for different injection timings. The experimental consequences show that the optimum injection timing is19º BTDC when using blend contained 40% Karanj and 60% Diesel. This injection time gives the lowest brake specific fuel consumption, highest brake thermal efficiency and lowest smoke density at a changed range of the load[14].

Abdullah studied the effects of using biodiesel blends on four-cylinder compression ignition engine emissions and performance. The biodiesel fuels were prepared by mixing alcohols and sunflower oil with presence sodium hydroxide. The sunflower oil is blended into percent of 5%,10%,15% and 20% by volume. The experimental results show the biodiesel reduced the engine emissions[15].

Swarup examined the biodiesel production from neat Mahua oil via base-catalysed transesterification and biodiesel mixing with a suitable additive (Dimethyl carbonate) in variable volume proportions to produce many types of trial fuel. The experimental work was accomplished by using a compression ignition engine of the single cylinder where water cooled at a variable load condition to test the emission and performance of the engine. Moreover, the practical outcomes display a rise in thermal brake efficiency and brake power using load. The thermal brake efficiency and brake power are improved by increasing the percentage of Mahua oil in the fuel. The biofuel is lowering the engine emissions[16].

Nantha investigated a comparative study of blends of biodiesel prepared from diesel and waste cooking oil in CI engines. The trial results show that the diesel and waste cooking biodiesel have similar properties. The biodiesel fuel causes a reduction in engine emissions and brakes thermal efficiency. Otherwise, combustion features and specific energy consumption of all biodiesel combinations showed similar trends when related to that of traditional diesel[17].

This paper seeks to study the outcome of using waste corn oil on compression ignition engine act. The experimental work was achieved on four strokes, single cylinder diesel engine to identify the effect of using waste corn oil on compression ignition engine performance. The waste corn oil was combined with the conventional diesel fuel. Moreover, different engine speeds were used in this work. Exhaust gas analyser was used to quantify the engine emissions. The analyser evaluates the percentage of the carbon monoxide, carbon dioxide, unburned hydrocarbon, and nitrogen oxide in the exhaust gases. In the present work, authors worked with a new type of fuel for the first time, and it was proved to be hopeful in improving the performance and reducing emission levels

## ENGINE PERFORMANCE MATHEMATICAL MODEL

Based on general heat engine thermodynamics, the engine performance can be simulated according to the following simple model :

1- Fuel mass flow rate.

$$\dot{m}_f = \frac{V_F}{\text{time}} \times \rho_F \quad {}^{\text{kg}}/_{\text{sec}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

2- brake power

$$bp = \frac{2\pi * N * T_b}{60 * 1000} \quad kW \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

3- Brake specific fuel consumption

$$\text{bsfc} = \frac{\dot{m}_f}{\text{bp}} \times 3600 \quad \frac{\text{kg}}{\text{kW.hr}} \ldots\ldots\ldots\ldots \ldots\ldots (3)$$

4- Air consumption (C.I. engine)

$$\dot{m}_{\text{a,act.}} = 2.056 \times 10^{-4} \times \sqrt{\nabla P} \; \frac{\text{kg}}{\text{sec}} \ldots\ldots\ldots\ldots (4)$$

5- brake thermal efficiency

$$\eta_{bth.} = \frac{bp}{\dot{m}_f * \text{L.C.V}} \quad \ldots\ldots\ldots \quad \ldots\ldots\ldots \quad (5)$$

Where;

$V_F$: the volume of fuel consumption.

$\rho_F$ :the density of fuel kg/m$^3$.

N: rotational speed rpm.

$Tb$: Torque of engine N.m.

∇P: pressure differences by the manometer.

## EXPERIMENTAL WORK

Experiments of this study were accomplished at Kerbala University. The test rig was completely designed and fabricated in an engineering laboratory, the test rig equipped with the instrumentation needed to accomplish the goal of general research and training studies.

### A. Experimental setup

The test rig includes four strokes; single cylinder diesel engine has a capacity of, 175 cm3, cooled by air, coupled with swing dynamometer via a belt to measure the brake torque and power as shown in figure.1.

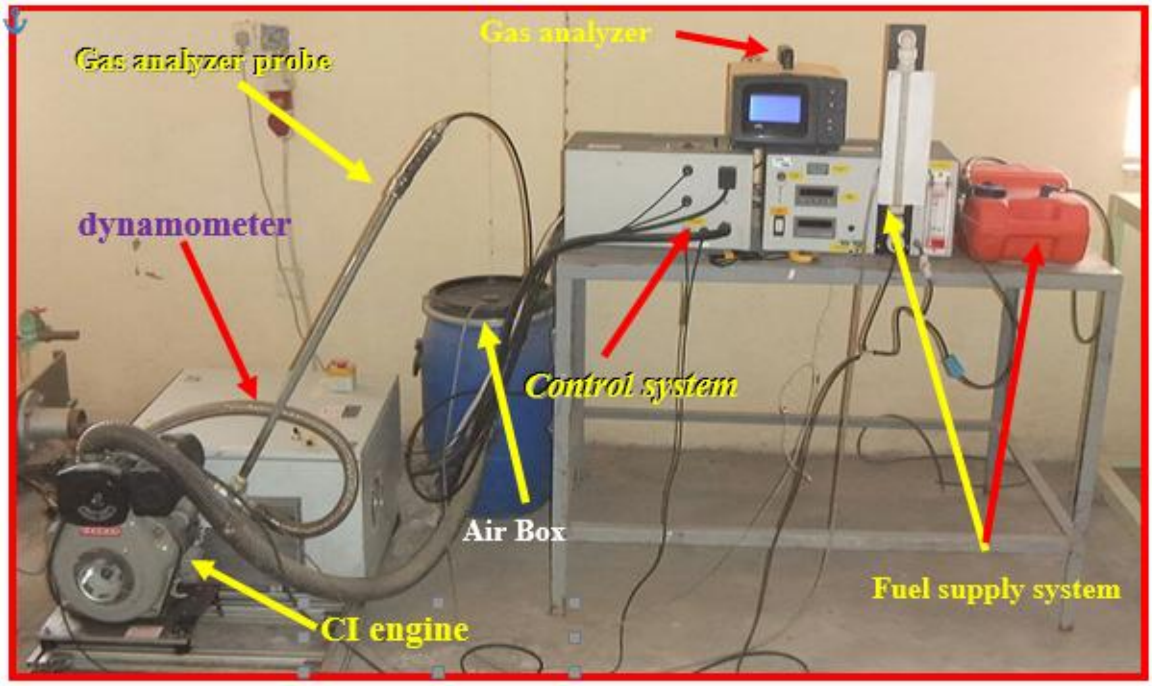


**Figure 1.** combustion system test rig

However technical specification is shown in Table (A.1). The dynamometer worked as a starter at first of engine operation and loaded the engine throughout of the engine operation. The dynamometer speed is regulated by using modern control system.

The engine parameter which can be calculated in this test rig is brake torque (N.M), engine speed (r.p.m), exhaust temperature, engine emissions, air consumption and fuel consumption. The brake torque is measured by using torque sensor which is installed beside the dynamometer. The torque sensor which is shown in figure .2 is loaded due to the large difference in speed between the dynamometer and engine to allow the dynamometer swing and exerted a load on torque sensor which generates the electric signal due to this load. The engine speed is measured by using speed sensor which is installed at the end of the dynamometer shaft.

**Table (A-1) Main technical conditions of compression ignition engine.**

| | |
|---|---|
| Engine type | Single cylinder, four stroke |
| Engine model | 95310 |
| Ignition timing | $25^0$ BTDC |
| Displacement | 118cm3 |
| Valve per cylinder | two |
| Bore | 60 mm |
| Stroke | 42 mm |
| Compression ratio | 17 |
| Engine cooling type | forced air cooled |
| Lubrication | Forced lubrication |
| Engine oil capacity | 1.5 L |
| engine rotation direction | counterclockwise (view from output shaft) |

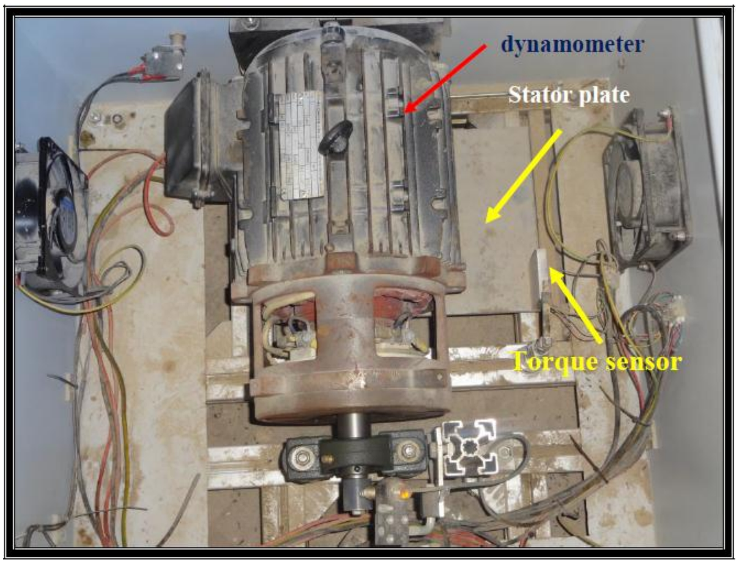


**Figure 2.** torque measuring system.

The fuel consumption is evaluated by using a scalar cylinder and stopwatch. The air consumption can be measured by using airbox which is connected to the engine intake manifold by using rubber pipe. Thermocouples were used to measure the exhaust temperature which is installed before the exhaust muffler.

Exhaust gas analyser type (mod 488 – Italy) was used to quantify the engine emissions. This analyser evaluates the percentage of the carbon monoxide, carbon dioxide, unburned hydrocarbon, and nitrogen oxide in the exhaust gases.

### B. Preparation of fuel samples

Samples were prepared by mixing conventional diesel with certain ratios of waste corn oil, the percent of mixing were (5%, 10%,15%,20%) by volume. The waste oil is filtered from pieces of foods then mixed with the diesel at constant temperature (60$^0$C) with the presence of KOH or NaOH to separate the gum material from waste corn oil and diesel fuel blend. The gum material causes engine damage because of it is causes compression ring sticking and fuel pipelines clogging. Therefore, that should be removed from the blend of diesel and waste cooking oil. The samples of biodiesel are shown in figure (3).


**Figure 3.** fuel samples.

### C. Experimental procedure

The steps below should be followed to accomplish the experimental procedure.

i. The instrumentation and engine test rig were set to standby mode. The biofuel samples were made available for use, before the test starting stage.

ii. Determining engine speed, the pressure differential between the atmosphere and pressure inside the airbox, brake torque and timing of fuel consumed for the volume of (100) ml with and without using biofuel.

## RESULTS AND DISCUSSION

The consequences achieved from the experimental work are presented here to reveal the impact of using biofuel prepared from waste cooking oil on compression ignition engine performance. The main operating variables which are measured throughout by the experimental work are break power, specific fuel consumption, engine emission, and percentage of waste corn oil presence in biofuel.

Summary of the major results are presented through the following concluded remarks:

i. In general the increasing in volumetric percent of mixing corn oil into value of (5%,10%,15%,20%)with (95%,90%,85%,80%) diesel fuel respectively, lead to raise the fuel consumption . The maximum increase of fuel consumption in corn oil and diesel blend is(11.4%) at 20% volumetric percentage of corn oil and 80% of diesel as shown in figure 4. This behaviour of increase in fuel consumption attributed to that the addition of waste corn oil causes a reduction in fuel heating value because of the existence of oxygen. The biodiesels have a lower calorific value than the diesel fuels.

ii. In general the increasing in volumetric percentage of mixing of waste corn oil in to volumetric percentage of (5%,10%,15%,20%) with (95%,90%,85%,80%) diesel fuel respectively, that cause increasing in specific fuel consumption. The maximum increase of the specific fuel consumption occurs when use corn oil and diesel blend is(11.4%) at 20% volumetric percentage of corn oil and 80% of diesel, as displayed in figure 5.

The tendency of the rise in fuel consumption associated with that the adding of waste corn oil to the diesel fuel causes a reduction in fuel heating value as a result of the presence of oxygen in biofuel.

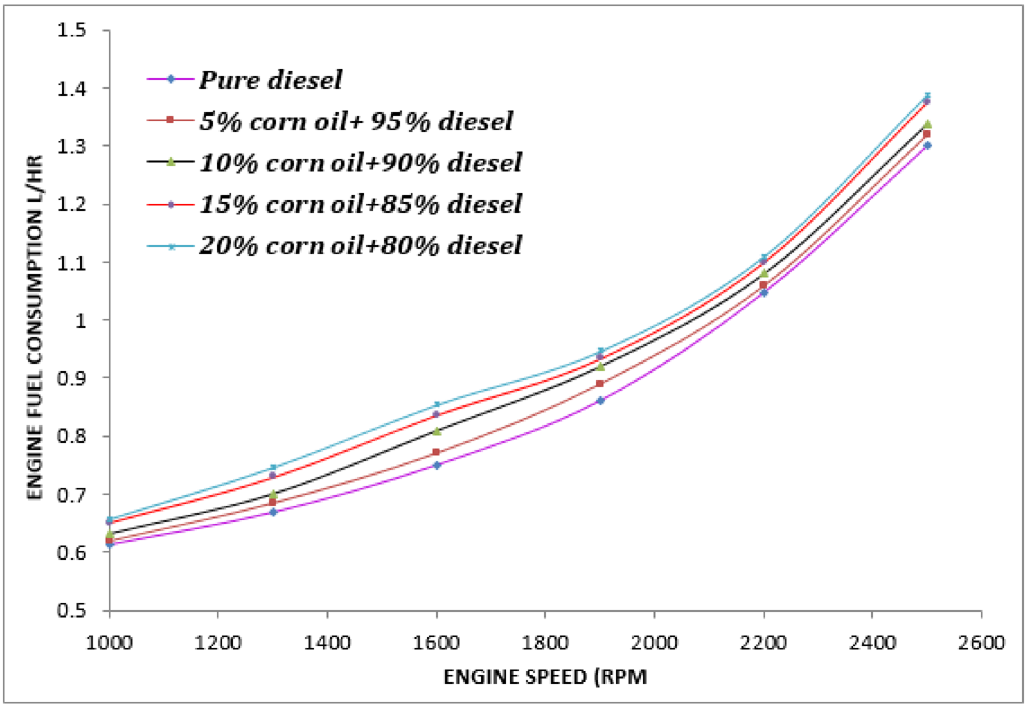


**Figure 4.** shows the relation between engine speed and fuel consumption (L/h) engine in C.I. engine with and without using biofuel.

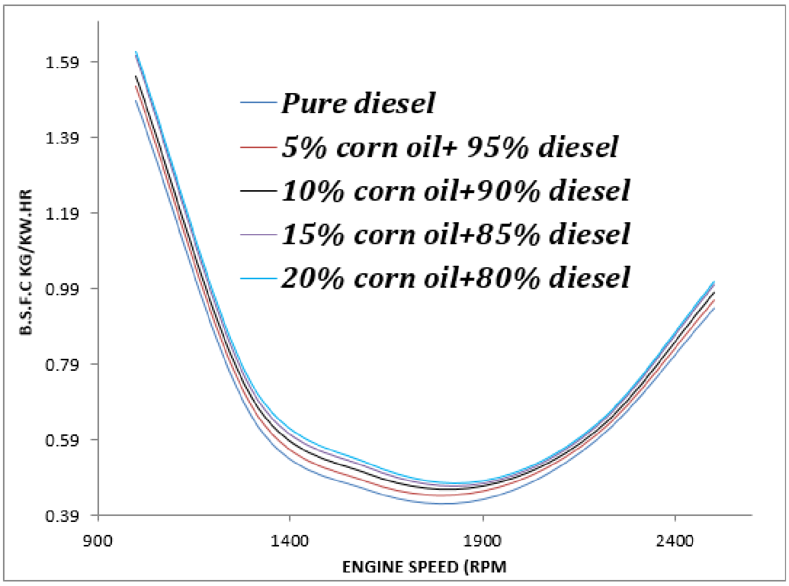


**Figure 5.** shows the relation between engine speed and b.s.f.c. in C.I. engine with and without using biofuel.

iii. The carbon monoxide emission reduced by increasing the amount of waste corn oil in a conventional diesel. The maximum lowering of CO emission when using diesel and waste corn oil blend is, (25.625%).This maximum of CO emission reduction occurs when using a mixture having 20% of corn oil and 80% conventional diesel. Figure 6, shows the decreasing in CO emission with rising the volumetric ratio of waste vegetable oil in a conventional diesel. This trend of reduction in CO emissions attributed to that the oxygen present in biofuel lead to optimum combustion. Moreover, CO emissions are greater for low excess air ratios in the situation of pure diesel as too many rich pockets last.

iv. The unburned hydrocarbon (UHC) emission decreased with increasing volumetric percentage of waste corn oil with the conventional diesel. The lowest (UHC) emission was (40.47%) when using diesel and corn oil blend.

This maximum reduction occurs when using a combination containing 20% of waste corn oil and 80% conventional diesel. Figure 7, shows the decreasing in (UHC) emission occurred with increasing the volumetric percentage of waste vegetable oil.

This trend of reduction in (UHC) emissions attributed to that the oxygen present in biofuel increasing the combustion efficiency.

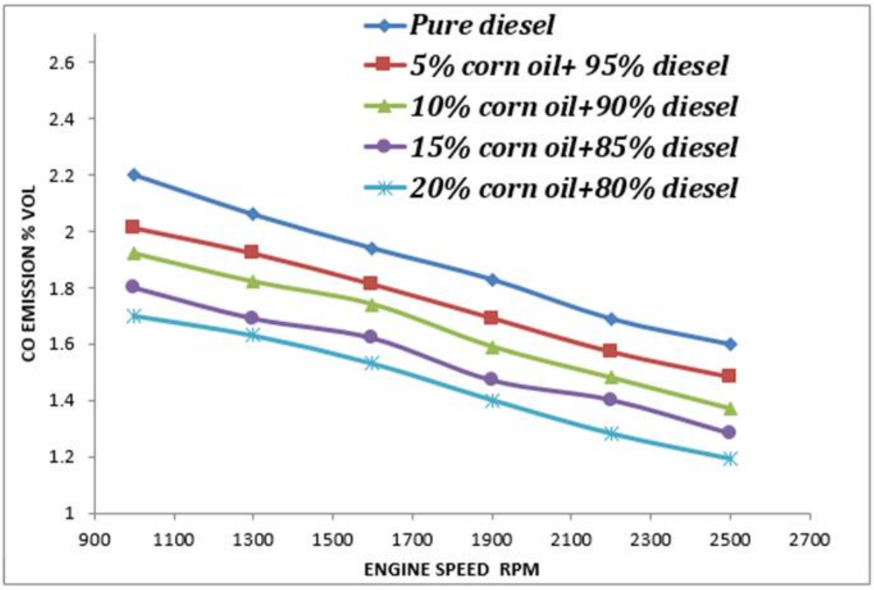


**Figure 6.** shows the relation between engine speed and (CO) emission in compression ignition engine with and without using biofuel.

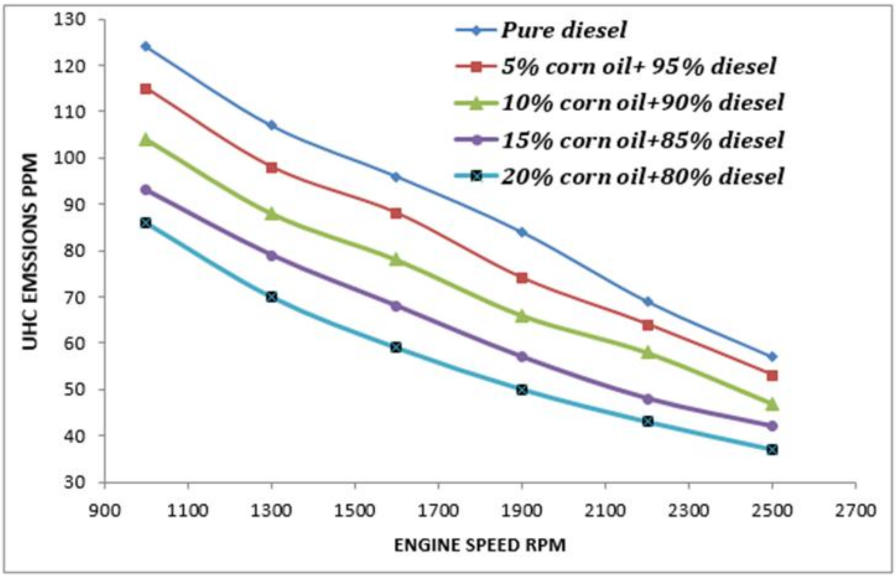


**Figure 7.** shows the relation between engine speed and (UHC) emission in compression ignition engine with and without using biofuel.

v. The nitrogen oxide ($NO_X$) emission is increasing with increasing volumetric percentage of waste corn oil in a traditional diesel. The maximum increase of ($NO_X$) emission was (29.92%) by using diesel and waste corn oil blend. This value occurred when using a combination containing 20% of corn oil and 80% conventional diesel. Figure 8, shows the rise in ($NO_X$) emission with increasing the volumetric ratio of vegetable oil in a conventional diesel. This behaviour of increasing in ($NO_X$) emissions attributed to that presence of oxygen in biofuel increase. The larger temperature reaction created by the additional oxygen and improved combustion in the saturated biodiesel could also cause greater Zeldovich emissions (thermal NOx)[18].

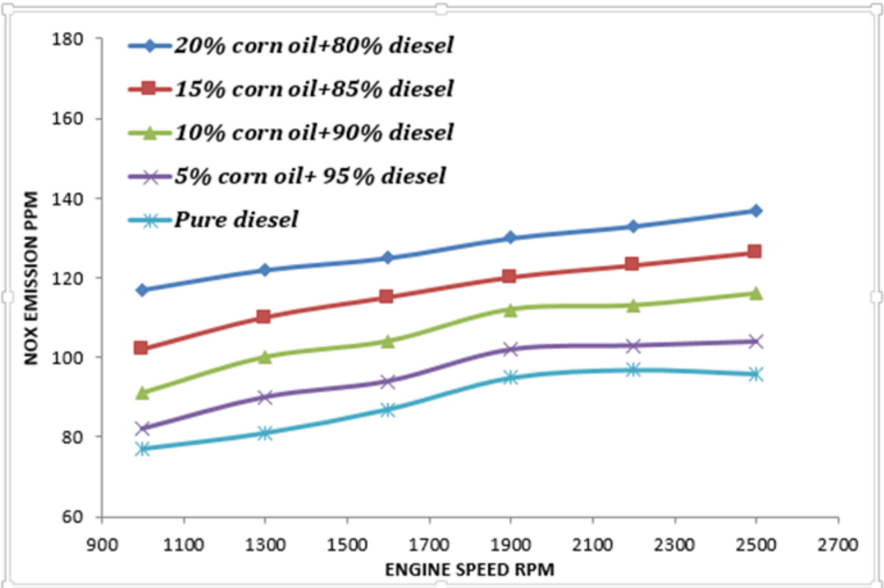


**Figure 8.** shows the relation between engine speed and NOX emission in compression ignition engine with and without using biofuel.

vi. The carbon dioxide ($CO_2$) emission increased with growing volumetric percentage of waste corn oil in biodiesel. The maximum increasing in ($CO_2$) emission when using diesel and corn oil blend is (41.20%).This maximum increases in emissions occur when using a mixture having 20% of corn oil and 80% conventional diesel.

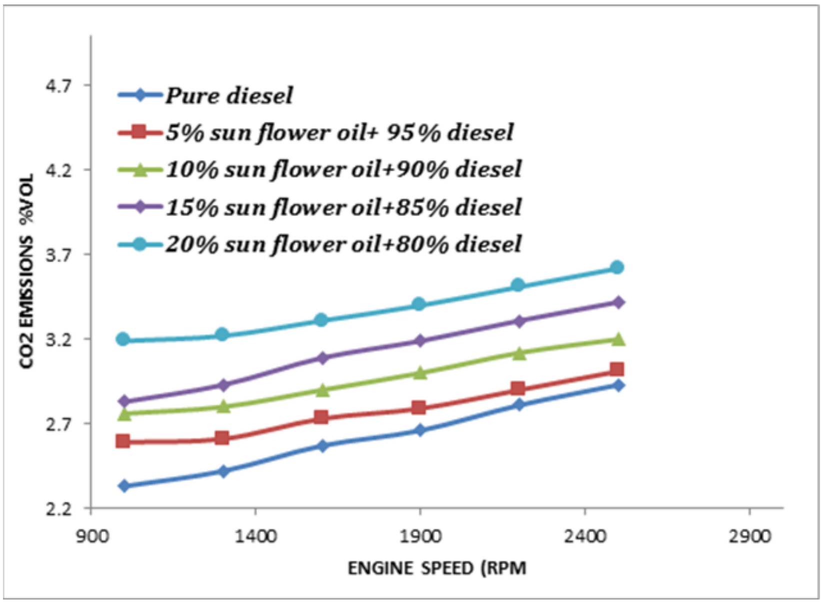


**Figure 9.** shows the relation between engine speed and ($CO_2$) emissions in C.I. engine with and without using biofuel.

Figure 9 demonstrates the increase in ($CO_2$) emission by increasing the volumetric percentage of waste vegetable oil in a conventional diesel. This behaviour of increasing in ($CO_2$) emissions attributed to that the oxygen present in biofuel lead to complete combustion and produce more carbon dioxide. Moreover, the high carbon dioxide emissions for the combinations was because of the existence of carbon monoxide in the fuels, with part of the CO created was converted into $CO_2$[19].

## CONCLUSIONS

The influences of using biodiesel prepared from waste cooking oil on compression ignition engine performance, for a range of engine speed and load can be concluded as below:

- Using biodiesel leads to reduce CO and HC emissions. This behaviour of reduction in these pollutants attributed to that the biodiesel has oxygen atoms in its chemical structure enhance the combustion process and give complete combustion.
- Employ biodiesel increased $CO_2$ and $NO_X$ emissions due to increasing the combustion efficiency.
- Utilizing biodiesel increase fuel consumption and specific fuel consumption as a result of the biodiesel has low heating value due to oxygen presence.

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