Experimental Investigation on Four Stroke CI Engine Using Corn Oil As Fuel

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Abstract— *Many studies have report that vegetable oil as an alternative fuel to diesel fuel in ci engines has increased during the last few years because reserves of petroleum fuel and its derivatives are decreasing rapidly, and also they have harmful effects on the environment. In the present study, corn oil was used as an alternative fuel in diesel engines. An experimental investigation was carried out on four-stroke direct injection diesel engine to find out the performance and emissions, running on corn oil methyl ester and its blends with diesel fuel. Results are showing that corn oil methyl ester and its blends with diesel fuel are generally comparable with diesel fuel, according to engine performance and emissions.*

Keywords— corn oil; Blends; Engine Performance; and Emissions

I. INTRODUCTION

In the present situation conventional fuel crisis is expected within short period of time due to decreasing fuel reserves. The knowledge on the environmental pollutions due to emissions created as a result of conventional fuelled engine emissions is increasing in our daily life. In some countries, which are not having enough petroleum reserves, the expenses for importing huge amount of petroleum products for industrial sectors, commercial, transport and , domestic and for the generation of power/mechanical energy, has drastically increased. By replacing even with a small amount of total petroleum consumption with an alternative fuels are having a significant effect on the environment and economy. Therefore alternative fuels, energy efficiency, energy conservation and management, and environmental protection became increasingly important. These situations have initiated the importance of alternative fuels, which will be renewable, sustainable, readily available, techno economically competitive, and environmentally friendly, (Barnwal and Sharma, 2005).

Biodiesels prepared from vegetable oils have been considered a promising option (Puhan et al. 2005).

Biodiesels, which are renewable, is widely available from a number of sources, is sustainable and its ability for using as fuel indiesel engines with a small modification, has very less sulfur content (very near to zero), and hence causes less environmental pollution than conventional fuel (Ramadhas et al., 2004).

A number of research works have shown that bio-diesel oils hold promise as alternative fuels for diesel engines; but, several chemical properties of oils, like high molecular weight and high viscosity, cause low volatility poor fuel atomization and, leading to incomplete combustion and severe engine deposits, piston ring sticking, injector coking, and (Dorado et al., 2004).

Huge number of Bio-diesel oil esters have been tried and trying as alternatives to diesel fuel. Many research papers have concluded that the usage of vegetable oil ester as a fuel in diesel engines results in a reduced harmful engine exhaust emissions and engine performance that is the equivalent of diesel fuel (Graboski and Mc-Cormick, 1998; Y¨ucesu et al., 2001; A l., 2004lmeida et al., 2002; Kalligeros et al., 2003; Pramanik, 2003; Huzayyin et al., 2004; Ramadhas et al., 2005).;Several researchers reported that the pollutants as emissions from bio-diesels are far less of the most regulated pollutants than standard diesel fuel. Greenhouse effect will be reduced by reducing the carbon dioxide (CO2) emissions with the use of biodiesel. Furthermore, hydrocarbons (HC), nitrogen oxides (NOx), diminishing carbon monoxide (CO), and smoke density improves quality of air (Alfuso et al., 1993; Choi et al., 1997; Baldassarri et a; Lee et al., 2004; Raheman and Phadatare, 2004;).

Essential oils that have been tested in diesel engines are soybean ,sunflower ,corn, sa□ower, cottonseed, and rapeseed, which are categorized as edible oils (Recep et al., 2001); however, some edible oils, such as neat corn oil, have not been comprehensively tested as alternative fuel in diesel engines. Nonetheless, some experimental investigations related to biodiesel produced from a corn sunflower oil mixture (Usta et al., 2004), and some basic testing with neat corn oil methyl ester (Altıparmak et al., 2004; G¨ul et al., 2005; have been performed.

II. EXPERIMENT

Transesterification of hazelnut kernel oil CORN was produced as an alternative fuel by the transesterification method. The hazelnut kernel oil used in the transesterification process was obtained from a commercial source. The percentage of oil converted to biodiesel using the transesterification process and the physical properties of the biodiesel that was produced changed according to the transesterification process conditions. Fuel for the engine experiment was produced under optimum reaction conditions, which were determined after a series of experiments.

Single-stage laboratory transesterification was performed in a small rectangular container equipped with an electrically operated stirrer. A photo of the transesterification system is shown in Figure 1. Cat-alysts (NaOH and KOH) dissolved in methanol were added to stirred and heated (60, 65, and 70 ˚C) oil in order to obtain mixtures with specific volumetric ratios (1:4, 1:5, and 1:6) of oil to methanol. Stirring continued for 1 h at constant temperature; then the mixture was separated in the same container and the glycerol was allowed to separate for a minimum of 3 h. After draining of the glycerol the methyl ester was washed twice with a 1:1 volume of distilled water for 1 h to remove excess methanol and glycerol. Residual water was removed by heating.

Fuel properties

Fuel properties for neat CORN and its blends were determined at the laboratories of TUBITAK-MAM(The Scientific and Technological Research Council of Turkey Marmara Research Center). In this report experimental CORN-diesel fuel blends are denoted as BX, indicting a blend including X% CORN (i.e. B5 indicates a blend including 5% CORN) and B100 indicates 100% CORN.

Viscosity and density were determined according to ASTM D88 and ASTM D4052, respectively. The percentage of methyl ester was determined by dividing the volume of methyl ester by the total volume of oil and methanol

Figure1.Transesterification system used for the prodution of HOME

Experimental set-up for performance and emissions measurements

The performance and emission parameters of pre-pared diesel fuel blends (B5, B10,B15,B20,B25) with corn oil have been studied and compared with diesel fuel. A schematic diagram of the experimental set up is shown in Figure 1. The diesel engine which is used for the study is a 4-stroke, single cylinder, direct injection, air-cooled engine. Specifications of the engine are given in Table 1. The engine was loaded with an electrical dynamometer rated at 10 kW and 380 V. The load on the dynamometer will be measured by using a strain gauge load sensor. An inductive pickup speed sensor was used to measure the speed of the engine. Consumption of fuel was measured with a burette (10 and 20 ml volumes) and a stopwatch. Lubricating oil, Exhaust gas, and air-fuel inlet temperatures were measured with K-type thermocouples. The engine started with neat diesel fuel and warmed up. The warm up period is assumed to be an end when the engine is reached to rated working condition (i.e. when the temperatures of engine lubricating oil reached 60 ± 10 ˚C). Operating Parameters, including fuel consumption, speed of operation, and load, were measured. Brake power, brake specific fuel consumption, brake specific energy consumption, and brake thermal efficiency were computed. Emissions, including carbon dioxide (CO_2), carbon monoxide (CO), and nitro-gen oxide (NOx) were measured using an exhaust gas analyzer, and smoke density was measured using a smoke analyzer. All measurements were recorded in triplicate to obtain average values. Engine performance and emissions characteristics are presented according to engine load. A photo of the experimental apparatus is shown in Figure 3.

Table 1. Main Characteristics of The Test Engine.

Trademark and model	Kirlosker

Number of cylinders	One
Bore	86 mm
Stroke	68 mm
Swept volume	395 cm^3
Compression ratio	18:1
Maximum engine speed	1500 rpm
Maximum engine power	3.7 kW
Maximum engine moment	21 Nm at 2200 rpm
Injector opening pressure	200 Bar
Number of nozzle hole	4
Fuel injection timing	20 BTDC

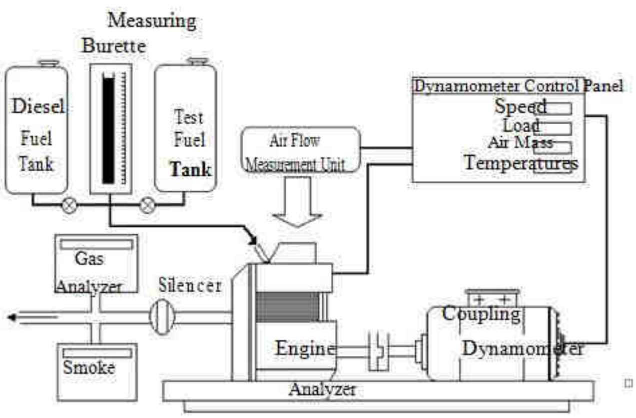

Figure 2. Schematic diagram of the experimental set-up.

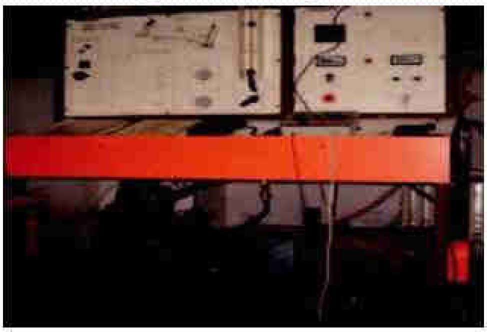

Figure 3. The experimental apparatus used for testing.

The accuracy in the measurements and the results of uncertainty analysis of the calculated results are shown in Table 2. Exhaust emissions and Engine performance have been studied at different engine loads and constant engine speed. Maximum torque was achieved at 1500 rpm.

Table 2. The Accuracy in the Measurements and the uncertainties in the Calculated Results.

Measurements	Accuracy
Load	± 2 N
Speed	± 2 rpm
Time	± 0. 5%
Temperatures	± 1 ^{o}C
CO	± 0.001%
HC	± 0.01%
NOx	± 1 ppm
Opacity	± 0.1%
Calculated results	Uncertainty
Power	± 2.55% max
BSFC	± 2.60% max
BTE	± 2.60% max

III. RESULTS AND DISCUSSIONS

Corn Production and its characterization

Variations in transesterification yield, viscosity, and density, with respect to reaction temperature, volumetric ratio of oil to methanol, and type of catalyst, are shown in Figures 4, 5, and 6, respectively. In the transesterification reaction higher methyl ester yield, higher density, and lower viscosity are de-sired; Therefore, as seen in the figures the optimum transesterification reaction conditions were reaction temperature 65 ˚C; volumetric ratio of reactants 1:5; catalyst KOH. The CORN used in the experiments was produced under these conditions

Biodiesel properties are very important and should be considered before testing in an engine. The kinematic viscosity of the corn and No. 2 diesel fuel used in the experiments were measured at 40 ˚C. Transesterification of corn oil provided a significant reduction in viscosity. The variation in corn viscosity was very close to that of the diesel fuel and was reduced further by increasing the amount of diesel in the blend. A similar reduction in specific gravity was also observed; however, the calorific value of corn was 37.23 MJ/kg, which is less than the calorific value of diesel (43.15 MJ/kg). As the percentage of diesel in the blends increased, the calorific value increased. The flash point of corn is determined to be ≥ 100^0c, indicating that can be safely stored and handled. The properties of No.2 diesel fuel and corn are given in table 3.

Engine performance

Brake thermal efficiency Variations in brake thermal efficiency (BTE), with respect to load, for all of the fuels of diesel and its blends are shown in Figure 7. BTE of all the tested fuels initially increased with engine load until it reached a maximum value and then decreased slightly as engine load continued to increase. According to the CORN content of the blends, BTE initially increased and reached a maximum value with the B20 blend and then decreased as the corn content in the blends increased.

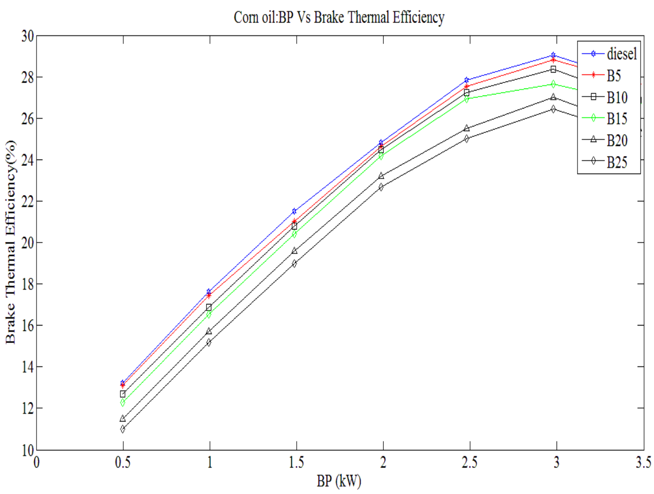

Figure 7. Variation in brake thermal efficiency.

Maximum brake thermal efficiency was 27.53% and 26.1% for B5 and B20, respectively, which was almost equal to that of diesel (27.73%). Maximum brake thermal efficiency was 25.32 B25 , which was lower than that of diesel fuel due to CORN's higher viscosity.

Although the addition of the CORN to diesel fuel decreased its heating value, higher BTE was obtained with B5 and B20. Corn includes approximately 10% (in weight) oxygen that can be used in combustion, especially in the fuel rich zone. This is one possible reason for its more complete combustion and higher BTE; however, as corn content in the blends increased (B25) BTE decreased due to lower heating value and higher viscosity, which result in slightly poorer atomization and combustion. By increasing the corn content in fuel blends the negative effects of CORN's lower heating value and higher viscosity outweigh the positive effect of CORN's oxygen content (Ramadhas et al., 2004; Usta et al., 2004).

Brake Specific fuel consumption Variations in brake specific fuel consumption (BSFC), with respect to engine load, of diesel fuel, CORN, and the experimental blends are presented in Figure 8. For all of the fuels tested, BSFC had a tendency to decrease as engine load increased until it reached a minimum value, and then slightly increased as engine load continued to increase.

BSFC initially decreased slightly as CORN content in the blends increased up to 20%, but increased as CORN content increased further due to CORN's lower calorific value and higher viscosity. In blends B5 and B20, BSFC was 0.33-0.35kg/kj, slightly more than diesel.

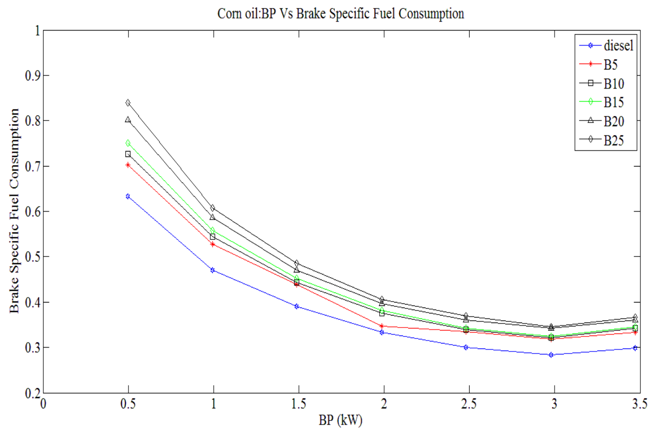

Figure 8. Variation in brake specific fuel consumption.

Exhaust gas temperature Exhaust gas temperature (EGT) varied with load and the results for different fuels are presented in Figure 9. EGT of all the tested fuels increased with load. EGT of B5 and B20 was higher than that of diesel fuel at the highest load due to the blends' higher viscosities, which resulted in poorer atomization, poorer evaporation, and extended combustion during the exhaust stroke. When CORN content increased (B25,) viscosity increased, and, as a result, EGT of the blends was lower than that of diesel fuel due to a deterioration in combustion and more fuel being oxidized. This was confirmed by BTE and BSFC measurements. Maximum EGT at peak load was 355 ˚C for B25 and 355 ˚C for diesel, while the maximum EGT of B20 was 346 ˚C,B5 was 332˚C.

Engine exhaust emission

Carbon monoxide Emissions Figure 10 compares the carbon monoxide (CO) emissions, with respect to engine load, of various fuels tested. CO emissions of all the fuels had a tendency to increase with load. CO emissions initially increased with CORN content in the blends, reaching a maximum value with the B20 blend and then decreased as CORN content continued to increase. B25 fuel had the lowest level of CO emissions. Higher amounts of CO in exhaust emissions are an indication of incomplete fuel combustion. As such, higher CO emissions of B20 indicated effective combustion due to the oxygen content of CORN, which improves fuel combustion. This was confirmed by variations in BTE and BSFC. Fuel blends with higher CORN content emitted lower amounts of CO emissions as a consequence of CORN's higher viscosity. The fuel spray cone angle, which depends on air entrainment, decreases with increased fuel viscosity. Decreasing the cone angle results in a reduction in the amount of air entrainment in the spray. Lack of sufficient air in the fuel spray impedes the completion of combustion and reduces CO emissions (Nwafor,2004).

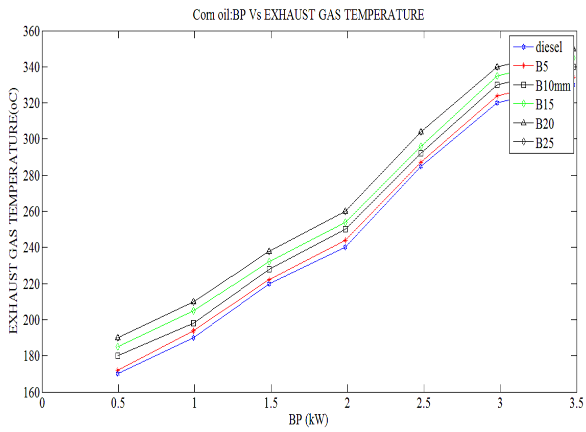

Figure 9. Variation in exhaust gas temperature

HC emission Figure 11 shows the plots for Hydro carbons (HC) emissions of the tested fuels operated at the rated engine speed of 1500 rpm at various load conditions. HC emissions increased with load because the air-fuel ratio decreased as the load increased, which is typical of internal combustion engines.

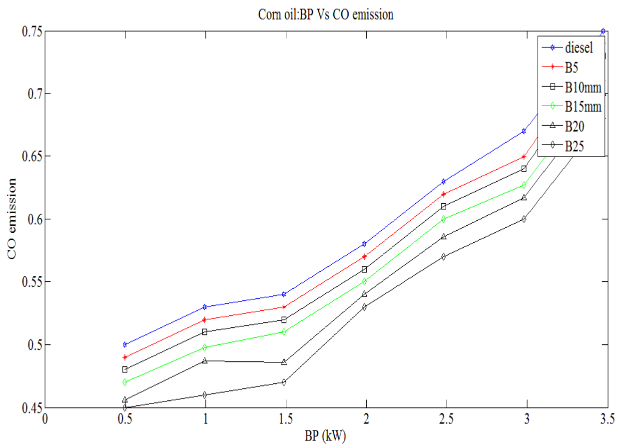

Figure 10.Variation in Co

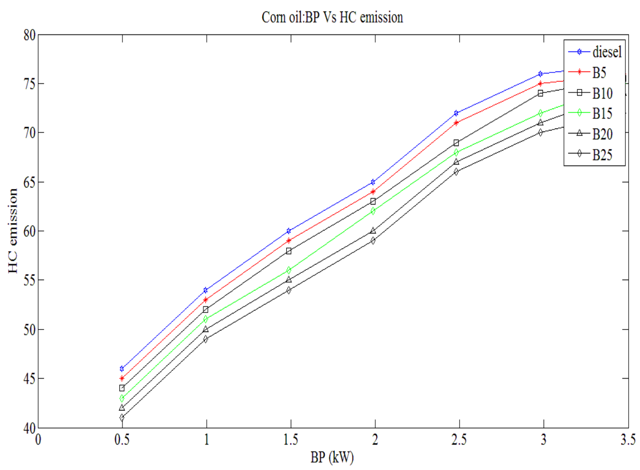

Figure 11.Variation in HC

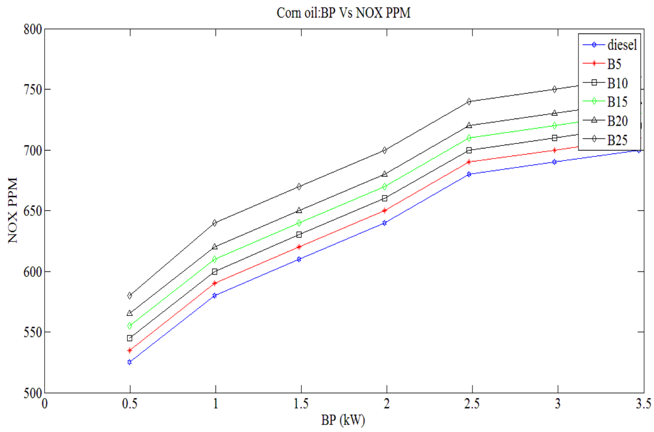

Figure 12.Variation in NO

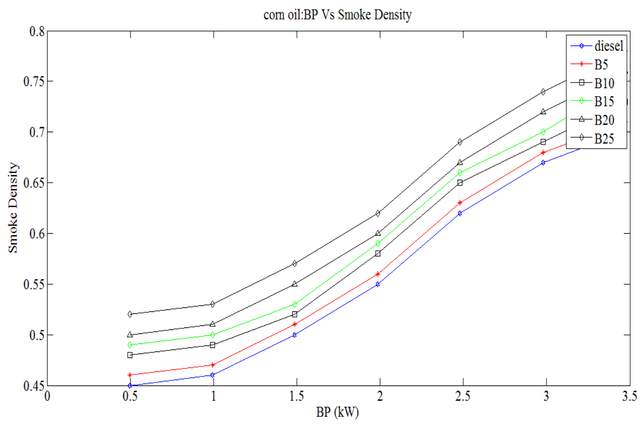

Figure 13: Variation in smokedensity.

Smoke density Figure 13 depicts the variation in smoke density with respect to the different fuels tested. As shown in the figure, smoke density decreased as CORN content in the blends increased, reaching a minimum value with B25. In diesel engines smoke formation generally occurs in the fuel-rich zone at high temperature, particularly within the core region of the fuel spray (Puhan et al., 2005). Because CORN contains oxygen, which decreases regional richness, the formation of smoke is reduced.

IV. CONCLUSION

In this present study, corn oil was evaluated as an attractive alternative fuel for utilization in diesel engines. Optimum transesterification reaction conditions of corn oil, with respect to volumetric ratio of the reactants, reaction temperature, and catalyst, were investigated. The test fuel (CORN) used in the experiments have produced under the optimum transesterification reaction conditions. Most Important characteristics of Corn and its blends with diesel fuel were similar to those of diesel fuel when compare with each other. CORN and its diesel fuel blends were studied extremely in a four-stroke direct injection single cylinder diesel engine, in terms of emissions characteristics and performance. By considering the experimental investigation of this study the following conclusions are drawn:

- The optimum transesterification reaction conditions for corn oil reaction were volumetric ratio of the reactants 1:5, temperature 65˚C;; catalyst KOH.
- The CORN content blends with 5 and 20%,(B5, B20) has improved BTE of the diesel engine and slightly increased BSFC. The maximum BTE increased to 27.58% with B20. Furthermore, B5 and B20 improved exhaust emissions.
- The highest CORN content blend (B25) resulted in significant improvements in emissions, but they did have better performance characteristics than diesel fuel. Nonetheless, small modifications may provide significant improvements in the performance of B25.

Consequently, biodiesel produced from corn oil have emerged as an attractive alternative fuel in to utilize in existing diesel engines. Using biodiesel produced from corn oil have less environmental pollution; however, improve the agricultural economy and benefit the environment; however, a cost analysis of CORN production compared to the price of conventional diesel fuel should be considered due to increase in the price of corn oil.

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