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Assessment of Biodiesel Derived from Waste Cooking Oil as an Alternative Fuel for Diesel Engines

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Abstract: Biodiesel has a vital role in recent years as an alternative fuel for diesel engines. In this study, biodiesel was produced from waste cooking oil by transesterification process with methyl alcohol in presence of sodium hydroxide as a catalyst and then was assessed as a fuel. This assessment has been made in view of its fuel properties as well as the performance characteristics of a diesel engine running using biodiesel or its blends with regular diesel fuel. The fuel properties considered were the flash point, pour point, calorific value, viscosity, cetane number, carbon residue, ash and sulfur percentages. The results have shown that the properties of the prepared biodiesel were in good agreement with the Egyptian standard specifications of diesel fuel. Moreover, it was advantageous over petrol diesel as the percentages of sulfur, ash and carbon residues were zeros. On the other hand, the performance of a diesel engine was evaluated in terms of the specific fuel consumption, thermal efficiency, exhaust gas temperature and air- fuel ratio when running using biodiesel or its blends with regular diesel fuels as compared to diesel fuel. The engine used was a four stroke single cylinder diesel engine which was run at a constant speed of 1500 rpm and at a variable engine loads. The engine test was made using biodiesel, diesel and blends of them containing 25, 50 and 75 % by volume. The results have shown that the thermal efficiency of the engine can be improved by blending biodiesel with regular diesel at 50% level. However, the use of pure biodiesel or its blends with regular diesel at percentages lower or higher than 50% will cause a reduction in the engine thermal efficiency.
Keywords: Waste Cooking Oil; Biodiesel; Diesel Fuel; Diesel engine; Performance.

1 Introduction

Recently, it becomes obvious that the whole world is facing two major problems concerning energy and environment. The first is the gradual depletion of natural resources of petroleum while the other is global warming. The first is attributed to the fast increase in world population as well as the increase in the energy consumption rate per capita. Global warming is due to the increase in carbon dioxide level in the atmosphere which is directly related to the excessive use of fossil fuels observed in recent decades. These two problems have motivated the world to look for other new sources of fuels which can be used as alternatives to those derived from petroleum and which are sustainable and at the same time they can reduce greenhouse gas emissions. One of the major fuels that are currently derived from petrol is diesel fuel that is used to operate the engines of most vehicles. Plant oils are considered the most promising energy source to produce a fuel alternative to diesel fuel[1,2,3,4,5,6,7,8,9,10]. They have two major advantages over petro- diesel as being sustainable and as it will reduce carbon dioxide emission. This is due to the fact that carbon dioxide released in burning plant oils is almost equal to the carbon dioxide tied up by the plant during photosynthesis and thus, it does not increase the net carbon dioxide concentration in the atmosphere. It is thus more environmentally friendly compared to regular diesel fuel (petro-diesel).However they need some chemical or physical modifications to reduce their viscosity to a limit acceptable for good atomization in the injector of the diesel engine. Chemical modification of plant oils to produce a less viscous products can be achieved either by transesterification of the oil with short chain alcohols in presence of a suitable alkaline or acidic catalysts or by oil cracking to hydrocarbons[1,2]. Biodiesel fuel which is chemically a blend of the esters of fatty acids with short chain alcohols is considered the most commonly used as a fuel substitute for diesel fuel obtained from petroleum. It is advantageous over regular diesel fuel as being renewable, free of sulfur and it is biodegradable. In addition, it has more lubricity which means smooth running of the engine.

Since Egypt imports huge quantities of edible oils annually to cover more than 90% of the consumption needs, it is completely unacceptable to produce this fuel in Egypt using vegetable oils that can be used for human consumption. Therefore, most previous studies carried out in Egypt in scope of biodiesel production were based on non edible oils. Examples of these oils are jatropha oil[2], rapeseed oil[3], used cooking oil[4] and rice bran oil[6]. A preliminarily feasibility study has proved that used cooking oil is currently the most suitable as a feed stock for an industrial production of biodiesel in Egypt[11]. The use of biodiesel derived from wasted cooking oil as an alternative fuel for diesel engines has received the interest of researchers in this field worldwide[12,13,14,15,16,17,18,19,20,21,22,23,24,25,26].

This work was proposed to assess the opportunity of utilizing the huge quantities of cooking oil currently wasted in Egypt for the production of biodiesel that can be used as an alternative to regular petrol diesel. This will be done in view of the fuel properties of the product as well as the performance of a diesel engine running using blends of regular diesel fuel with the produced biodiesel as compared to that using regular petro-diesel.

2Experimental Work

The experimental work carried out in this work includes three consecutive steps. They include the preparation of biodiesel from used cooking oil, evaluation of its main properties as a fuel and the last is the testing of the performance of a diesel engine running using blends of the produced biodiesel and regular diesel fuel.

2.1 Production of biodiesel from waste cooking oil

Waste cooking oil was collected from several restaurants located in cairo and six october city.It has been first filtered from any solid particulates. The oil was then transesterified using alkaline catalyst (sodium hydroxide). The exact quantity of sodium hydroxide used was calculated so that its percentage in the batch is about 1% of the reaction mixture after making up for the quantity needed to neutralize the free acids in the oil. The molar ratio of methanol to oil was 6:1 which is more than the stoichiometric quantity as to force the reaction process which is reversible in the forward direction until being completed. The catalyst was the neutralized using sulfuric acid and the excess alcohol recovered. The glycerin which was formed as a byproduct of the process was separated from biodiesel by gravity separation. A schematic description of the process usually used for biodiesel production is illustrated in Fig.1.

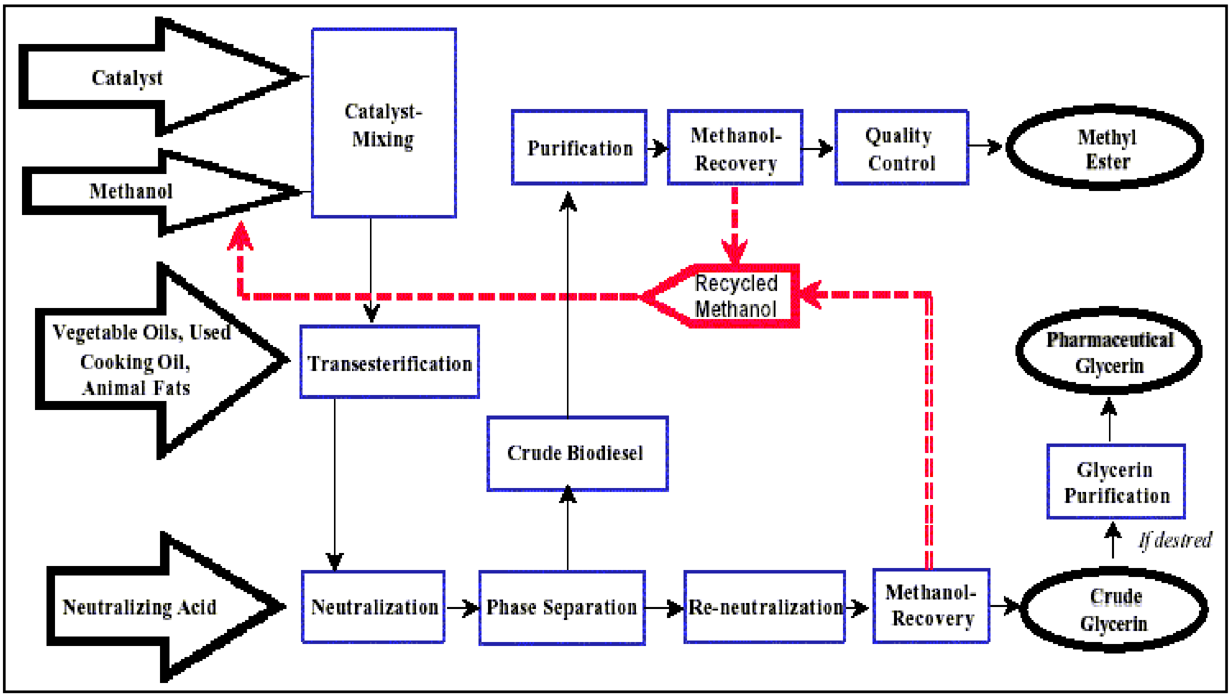


Figure1: Process flow sheet for the production of biodiesel fuel by conventional homogenous transesterification of oil using alkaline catalyst

2.2 Testing the fuel properties of the prepared biodiesel

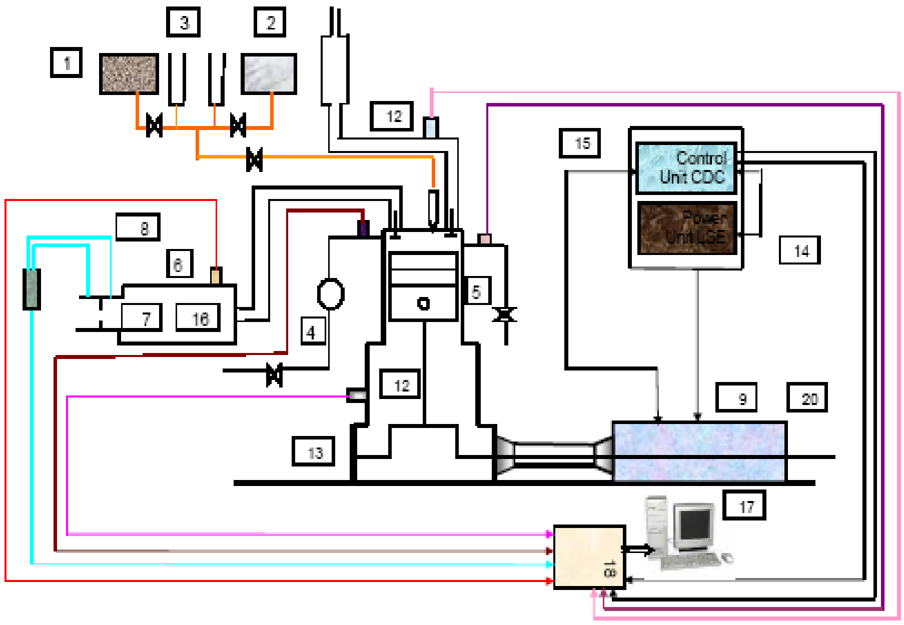
The properties of the prepared biodiesel relevant to its performance as a fuel for a diesel engine have been determined in the central analytical laboratory at the Egyptian Petroleum Research Institute, EPRI, Nasr City, Cairo following the standard methods of analysis (ASTM). These include the calorific value (ASTM D-224), Flash point (ASTM D-93), carbon residue (ASTM D-189), ash% (ASTM D- 482) sulfur% (ASTM D-4294), pour point (ASTM D-9), Kinematic viscosity (ASTM D-445) and density (ASTM D-4052).

2.3 Engine Testing

The diesel engine used for testing the produced fuels was a single cylinder, four strokes, water cooled and direct injection diesel engine. The diameter of the engine cylinder was 85 mm while the piston stroke was 110 mm. The compression ratio was 17.5:1.A schematic diagram of the experimental set-up used for the engine test is illustrated in Figure1.

The engine was connected to an eddy current dynamometer to measure the engine output power and speed. The diesel engine received air through an air box fitted with an orifice for measuring the air consumption. The differential pressure meter is measured between the two sides of the orifice. The rate of fuel consumption was determined using a glass burette and stop watch. A digital tachometer was used to measure the engine speed. A data acquisition card was used to collect data to be fed to a personal computer. The schematic diagram of experimental set-up is shown in Figure 2.

The engine was warmed up before taking all measurements. When the engine reached its stable running conditions, the experimental measurements were recorded. The engine was operated using regular diesel fuel, biodiesel of waste cooking oil as well as blends of diesel and waste cooking oil biodiesel containing 25,50 and 75% of biodiesel namely B25, B50and B75, respectively. The engine speed was adjusted and maintained constant at 1500 rpm. The fuel consumption as well as the engine power, air- fuel ratio and exhaust gas temperature were recorded during the engine running tests at different engine loadings. Hence the specific fuel consumption as well as the thermal efficiency were estimated in each case.



1- Diesel Tank	2- Biodiesel Tank
3- Burette	4- Inlet water temperature sensor
5- Outlet water temperature sensor	6- Intake air temperature sensor
7- Orifice	8- pressure differential sensor
9- Dynomemeter	10- Power unit
11- Exhaust temperature sensor	12- Oil temperature sensor
13- Diesel engine	14- power unit
15- Control unit	16- Air tank
17- Personal computer	18- Data acquisition card

Figure 2: Schematic Diagram of the Experimental Set-up Used For Diesel Engine Testing.

3. Results and Discussion

3.1 Fuel properties of biodiesel as compared to Egyptian standard specifications of diesel fuel

The results concerning the main properties of the prepared biodiesel relevant to its use as a fuel for diesel engine as compared to the Egyptian standard specifications of diesel fuel are listed in Table.1.It is obvious that the properties of biodiesel prepared using waste cooking oil agree well with the recommended Egyptian standard specifications of diesel fuel. Moreover, it is advantageous over petrol diesel as it was completely free of sulfur. This means less formation of corrosive sulfur acidic oxides upon the combustion process which means that the combustion exhaust will be less polluting to the environment. Also, the fuel burning is expected to leave neither ashes nor carbon deposits in the engine parts since the ash percentages as well as the carbon residue percentage were both zero as depicted in Table.1.Excessive carbon deposits as well as ashes in the engine are known to cause some troubles during engine running especially upon long term use.

Table1 Fuel properties of biodiesel as compared to standard Egyptian specifications of diesel fuel

Property	Biodiesel	Regular diesel
Specific gravity	0.836	0.82-0.87
Kinematic viscosity, cSt, @ 40° C	5.1	≤7
Total sulfur, wt. %	Nil	≤1.2
Pour point, °C	6	4.5-15
Flash point, °C	91	≥55
Ash content, wt.%	Nil	≤0.01
Carbon residue, wt.%	Nil	≤0.1
Cetane number	59.82	≥55
Calorific value KJ / Kg	40000	42000

3.2 Results of Engine Testing

The effect of blending biodiesel with diesel fuel on the estimated values of the specific fuel consumption as well as the thermal efficiency at different engine loadings is illustrated in Fig.3 and 4.It is clear that the specific fuel consumption increased with increasing engine load and it was higher in case of biodiesel compared to regular diesel. This is quite expected since the heating value of biodiesel was lower than that of regular diesel. At full load, the specific fuel consumption using biodiesel was 28% higher than that by using regular diesel fuel. However, blending regular diesel fuel with an equal volume of biodiesel (B50) resulted in a reduction in the fuel consumption rate by about 10%.It may be that the efficiency of the combustion process using this 50% blend was higher.

The variation in the fuel consumption rate has been directly reflected on the estimated values of the thermal efficiency in Fig.4. The estimated thermal efficiencies using diesel- biodiesel blends as fuels of the diesel engine were close to that of diesel fuel. At full load, the thermal efficiency using biodiesel was 19.5% compared to 23% using regular diesel fuel .However, blending regular diesel with an equal volume of biodiesel can markedly improve the thermal efficiency whereby it increased from 23 to 26% by such blending.

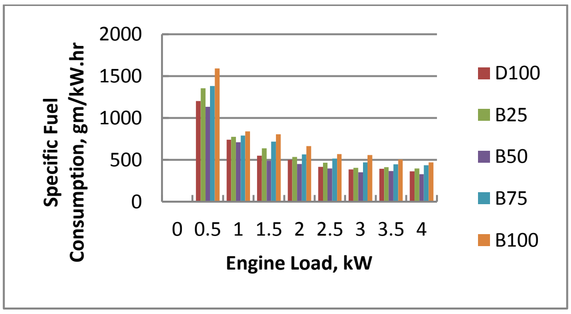


Figure 3: Brake specific fuel consumption at different engine loads using biodiesel, diesel and their blends.

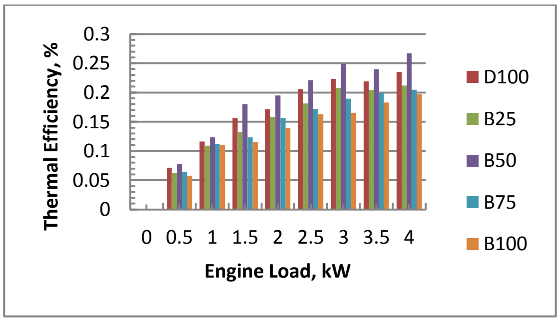


Figure 4: Thermal efficiency at different engine loads using biodiesel, diesel and their blends.

The variations in the temperature of the exhaust from the combustion of diesel, biodiesel and their blends at different engine loads are shown in Fig.5. In general, the exhaust gas temperature increased by increasing the engine loading due to the increase in the fuel consumption rate .It can be also observed that the exhaust gas temperature was lowest using a fuel blend of equal volumes of diesel and biodiesel (B50) which is being quite expected since the rate of specific fuel consumption using this blend was the lowest. At full engine load, the exhaust gas temperatures for biodiesel; B100 and its blends with regular diesel; B25, B50 and B75 were 345, 325, 305 and 334 °C, respectively compared to 315 °C in case of regular diesel fuel.

The changes in air-fuel ratios with engine load for diesel, biodiesel and their blends are shown in Figure 6. Lower air to fuel ratio which means a mixture richer in the fuel is needed at higher engine loads. Lower air to fuel ratio is also needed when using biodiesel as alternative to regular diesel fuel. However, the situation can be reversed by blending diesel fuel with biodiesel at 50% level.

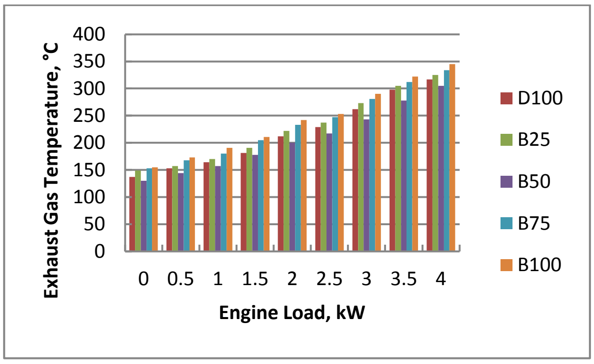


Figure 5: Exhaust gas temperature at different engine loads using biodiesel blends with diesel fuel.

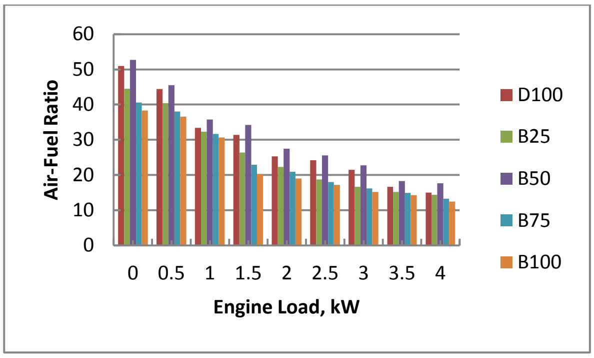


Figure 6: Air- Fuel ratio at different engine loads using biodiesel blends with diesel fuel.

4. Conclusion

According to the results of this work, it can be stated that waste cooking oil can be used as a suitable feed stock for production of biodiesel fuel that can be successfully used as an alternative fuel for diesel engines especially when mixed with an equal volume of regular diesel fuel (B50).

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