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Minimise Environmental Pollution Due To the Use of Vegetable Oil as an Alternative Fuel in Diesel Engine

تقليل نسبة التلوث البيئي الناجم عن استخدام الزيوت النباتية كبديل للوقود في محركات الديزل

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Abstract

Gaza Strip has a long history of critical shortage in its fuel supply due to the economic siege imposed by the Israeli national policy. Not surprisingly, therefore, alternative solutions have been sought ever since which replace the use of diesel in car engines with all kinds of vegetable oils. Nevertheless, such alternative shows drawbacks in relation to badly affecting the surrounding environment. This study focuses on these drawbacks in an effort to minimise environmental pollution emerged due to using vegetable oil as an alternative energy resource to fuel engine. In so doing, analysis in this article uses the Gaza Strip as a particular case. A comparison is utilised in this case through the lens of heat efficiency which compares between the proportions of environmental pollution, firstly emerged due to the combustion of vegetable oil and secondly occurred in the engine diesel. The next step seeks to minimize the proportion adopting handling heating that uses additional materials, small organic molecules, acetone and toluene. These materials reduce environmental pollution in comparison with diesel engine, thereby enhancing its efficiency. Analysis in this study uses three different mixtures of alternative fuels based on vegetable oil (VO). In the first fuel, the VO contains different percentage of acetone. The second one has VO with different percentage of diesel. The last fuel shows 80%VO, 20% diesel and different percentage of acetone. This study argues that the best performance similarly to the efficiency of fuel diesel was measured at 2%-10% acetone for the first mixture, 20%-40% diesel for the second one and at 5%-10% acetone for the last one. From the perspective of ecology, the third mixture reveals the best outcomes amongst others because it minimises the CO_2 emissions in relation to the VO. It reaches between 13.5% and 15%. In a similar vein, the NO_2 emission was minimized at a percentage that reaches between 4% and 16%. All the above results were accepted at $\alpha=1$ due to balancing between CO_2 and NO_2 emissions.

Key words: vegetable oils, Alternatives, incomplete combustion, pollution**.**

ملخص

يعاني قطاع غزة من نقص شديد في الوقود بسبب الحصار الذي يفرضه الاحتلال على القطاع، مما أثر على نواحي الحياة المختلفة للمواطنين خصوصا في قطاع المواصلات مما دفعهم إلي إيجاد بدائل عن الديزل مثل الزيوت النباتية بأنواعها المختلفة التي أدى استخدامها في محركات السيارات الي زيادة نسبة التلوث البيئي الناجم عن عدم احتراق تام للزيوت. تهدف هذه الدراسة إلى تقليل نسبة التلوث البيئي العالي الناجم عن استخدام الزيوت النباتية. بدأ بإجراءات مقارنة بين نسبة التلوث الناتج عن احتراق الزيوت النباتية بتلك الناجمة عن احتراق الديزل. و العمل من اجل تقليل هذه النسبة من خلال المعالجات الحرارية وذلك بإضافة مواد مذيبة مثل: الاستون و الطالون وغيرها التي تعمل على تقليل نسبة التلوث مقارنة بالديزل ورفع كفائتة الحرارية. في هذه الدراسة تم عرض ثلاثة انواع من مركبات الوقود البديل للديزل حيث تعتمد على الزيوت النباتية وهي: الزيوت النباتية مع إضافة نسب مختلفة من الاستون، والزيوت النباتية مع إضافة نسب مختلفة من الديزل، كذلك الوقود المركب المكون من 80% زيوت نباتية مع 20% ديزل مع إضافة نسب مختلفة من الاستون كمادة مذيبة. نتائج التجارب على الأنواع الثلاثة أعطت أن 2% إلى 10% استون للوقود الأول، 20%-40% ديزل للوقود الثاني و5% الى 10% استون للوقود الثالث . من وجهة نظر بيئية فان أفضل النتائج هي نتائج الوقود المركب الثالث عند إضافة 5% الى 10% استون الى المركب الذي يعمل على تقليل نسبة CO_2 من 13.5% الى 15%، و تقليل نسبة NO_2 من 4 % إلى 16% بالمقارنة مع نسبة التلوث الناتج من احتراق الزيوت النباتية عند $\alpha=1$.

الكلمات المفتاحية: الزيوت النباتية، بدائل، احتراق غير تام، تلوث.

Introduction

Owing to the badly affected field of energy in the Gaza Strip alternative solutions have been sought which directly respond to the critical shortages in fuel supply. One solution uses vegetable oil (VO). However, this solution has been widely utilized without knowing beforehand the ratios embodied in scientific bases. Mechanical and serious environmental problems follow. In an attempt to remedy these problems, analysis in this study develops practical solutions that directly remedy the fuel shortages in general – that is, a mixture of fuel is advocated in this study because of its thermal and physical nature, thereby converging diesel fuel and gasoline businesses.

Analysis in this study therefore shows how a mixture of fuel could be utilized as a useful source, replacing first the widely used fuel diesel and secondly having less impact on the surrounding environment. To test this hypothesis, analysis cited here proceeds as follows. The section that follows reviews the literature of concern, followed by discussing what solutions are available to the research problem highlighted previously. These solutions concern the right proportions that help produce a mixture fuel, followed by narrating the experimental results. The conclusions are then drawn in a final section.

Literature review

Existing research (Kapilan & Reddy, 2008) shows a strong interest in alternative solutions to fuel used in developing countries in particular. Indeed, many of the experiments related to alternative fuel (Ziejewski and Kaufman, 1983) have investigated the use of vegetable oils to be blended with diesel. As a result, problems arise in the process of burning. Another example is Gerhard (1983) who has examined the high level of viscosity in conjunction with the low level of volatility inherited in pure vegetable oil in an attempt to reduce the fuel atomization, thereby increasing the fuel spray penetration. Note that the higher spray penetration and polymerization of the unsaturated fatty acids are at high temperatures which are partly responsible for the difficulties experienced in engine deposits and also in increasing the viscosity of the lubricating oil. A serious lack of fuel supply therefore emerges in these countries. To remedy this lack, attempts have been made to decrease fuel consumption being used in these countries by combining other available oils to petrol. As Musalam and Kuchmambetov (2003) suggest, coal and water could be added to Slurry in an effort to arrive at unique combination (CWS). Central to this combination is the use of heat treatment towards achieving appropriate thermal performance that is as same as that of diesel. Musalam and Kuchmambetov (2003) go further and argue that the combination is effective in power plant because it limits the fuel consumption and, more importantly, add CaO in an effort to decrease NO_x and CO_2 in fuel combustion. This addition is labeled heating treatment in accord to analysis in this study.

Another example is VO that may be used as a substitute to diesel fuel. The example uses mahua oil, defined as one type of vegetable oil that is preheated to 130^{o}C so that a decrease in viscosity could be reached. On the other, a decrease in NO_x is feasible. In this respect, Mahau oil in practice replaces fuel diesel in engine diesel and in particular in emergency situations (Pugazhvadivu and Sankaranarayanan, 2010). Briefly, as Puhan et al (2009) report, Mahua (M. indica) stems from seed oil that could be used for manufacturing related to biodiesel, for example soap industry. Puhan et al (2009) draw on a different method of using the Mahua oil. In this method, different alcohols are added in a single-cylinder direct injection (DI) diesel engine to Mahua oil. Mixture of all the esters was accordingly evaluated in relation to engine performance and emissions. The CO emissions from all the esters were also at lower level than those stemming from diesel fuel measured at full load. This is because CO_2 emission compared with diesel, in accord to Puhan et al's example, a better combustion than the different fuel mixture. Indeed, the NO_x emissions for all fuel mixture with the esters were lower than that of the diesel.

A further example to the use of VO in existing research is the use of mahua methyl ester produced from non-edible vegetable oil (M. Indica), including its blends in conjunction with diesel fuel (Ghosal et al, 2008). In this respect, tests related to performance of the short-term engine were conducted adopting four different blends of mahua methyl ester oil, in addition to diesel fuel. In so doing, ester oil was mixed with diesel fuel in accord to rate of 20, 40, 60 and 100 by heating the fuel at the temperatures (T-re) 30, 50 and 70^{o}C and using two injection pressures (17640 kPa and 24010 kPa), respectively. As a note, an electrical heating unit was utilized in an effort to limit the viscosity of vegetable oil. As a result, three measures emerge in relation to the fuel mixture of mahua and diesel. These are the values of power output at 3%, specific fuel consumption at 9% and exhaust gas temperature at 0.5%. Notably, the measures emerge as a result of the blend at 20% mahua methyl ester and 80% diesel at different temperatures which are less than the pure diesel fuel. Therefore, Mahua methyl ester could be used as a substitute for diesel fuel in compression ignition engine.

The above examples, as sketched above, show that Jatropha (one type of VO) could be used in diesel engine without applying any modification to the diesel engine. This particular fuel has a slight increase in thermal efficiency in comparison with diesel; however, it has a low CO_2 emission (Hanumsnths et al, 2009). In particular, Jatropha uses vegetable fat in diesel engine. It should be also noted that fat in this regard neither fits smoothly in fuel supply system nor burns effectively. This is because Jatropha has a high rate in viscosity that causes blockage on filters/nozzles. As a result, fat on the one hand needs to be heated at around 60^{o}C so that problems aroused from viscosity could be solved. On the other, as Nicholson (2007) reports, 10% to 20% of a natural solvent, such as turpentine, may be added to Jatropha.

VO could be therefore adopted as a source of fuel for vehicle engines. However, adaption remains essential but it depends on the type of oil and its peculiarities, or better stated, the kind of engine being used. In this vein, some engines require mechanical alterations to be applied to the system of feeding fuel when using alternative fuel, such as fuel filter and injector pumping. This is because the high level of viscosity obstructs the sprayers. To stem the failure, three methods are necessary. One modifies the fuel needed for straight burning in diesel engine. The second concerns applying mechanical adaptation in fuel supply system.

The final method addresses the question of how the design engine is capable to burn fuel.

In the end, analysis in this study examines particular problems tied to environmental pollution, thereby attempting to suggest solutions of concern. It uses the Gaza strip as a case study in emergency situations associated with acute fuel problems.

Suggested approach

As previously discussed, an alternative is sought that directly respond to the shortage in fuel using working Heat Comparisons in conjunction with diesel in the effort to arrive at the appropriate combination, suitable to diesel engines, whilst noting that this combination stresses that there would be no need for mechanical and thermal modifications.

This is due to the lack of possibilities that enable the design of a special/alternative fuel without the need to apply a mechanical change in car engines. In so doing, this study develops a fuel mixture. The aim is to decrease the consumption of diesel as minimum as 80%. This mixture consists of solvents, such as acetone or diesel, added at certain ratios to VO or diesel. To enable a comparison in the change occurred in the thermal behaviour between the mixture and the diesel appropriate percentages of the components included in the mixture is a must. Any error occurred when outlining the percentages leads to the following:

1. The inability of the supply system due to high viscosity of the alternative fuel, problems with the filtering system and not being able to control the amount of air measured in the engine;
2. Heat problems, such as high or low engine temperature, may results in engine malfunction and damage;
3. The problems associated with energy losses caused by incomplete or poor combustions; and
4. An increase in exhaust product of combustion processes may have a negative impact on environmental pollutions.

Having studied the above errors, analysis in this study compares the thermal behaviours of both the fuel mixture combustion and diesel. The comparison occurs in a burning environment in an effort to arrive at the composition that contains almost the same thermal properties as diesel. Table 1 shows the properties of VO, diesel and acetone. Acetone is selected owing to its solvation power appropriate for the mixture fuel and also because of its heat efficiency and activator property.

Table (1): The properties of VO, diesel and acetone.

Property	Vegetable oil	Diesel	Acetone
Heat of combustion, kJ/kg	39641	44121	45673
Density, kg/m^3	917	812	791
Viscosity, at 22^{o}C, mPa.s	54.3	4.3	0.32
Cp, kJ/kg.K	1.67	1.7	2.15

Source: Tuttle and Kuegelgen (2004).

Methodology and Experimental setup

To outline a mixture of fuel, the right proportions of mixture fuel as in diesel are key. Markedly, these proportions reveal the same result as suggested in this study. As discussed previously, the third type of mixture fuel shows 80%VO, and 20% diesels in accord to a huge numbers of experiments carried out for the conference paper presented at Al-Aqsa University, Palestine (Musalam, 2011). Notably, each step necessary to outline one proportion was carried three times in the combustion chamber observing the optimal average.

The heat treatment represents a method necessary to determine the appropriate proportions of mixture fuel by adding active chemical solvent, for example Acetone, to VO (Musalam, 2011). The aim enhances the heat efficiency and disconnects the ties of the molecules, thereby reaching the heat efficiency as same as diesel. This aim is achieved through firstly a gradual change in the proportion of Acetone added to the mixture fuel and, secondly, through noting the change occurred in the heat of mixture fuel which is compared with that occurred in the heat characteristic of diesel. In addition, measuring the temperature released in the combustion through analyzing both the ashes and the gas emission, for example CO_x and NO_x, could also fulfill the aim. Overall, the above methods seek to achieve alternative fuel that has similar heat features to diesel without applying mechanical changes to the diesel engine.

The method adopted to collect data in this study is quantitative ones that use burning station which determine the heat efficiency for each fuel, and analyse the exhaust gases. This station composed from three fuel tanks, air compressor (PARTSMART SMR4413 Assembly 4413 Freightliner Compressor), three thermocouples (N-type (Nicrosil–Nisil®)), exhaust analyser (hot-selling SV-5Q car exhaust gas analyser) and the burning chamber which is a local build one from old kamaz truck engine (kamaz is a Russian made trucks) and the station is shown in Fig.1 that provided by College of Science & Technology in Gaza. In this study three different mixtures of alternative fuels are used taking into account the three components inherent in the mixture fuel. One component shows that VO has different percentage of acetone while the second relates VO with different percentage of diesel and finally the third mixture is 80%VO+20%diesel, showing different percentage of acetone.

The first thermocouples measured the burning temperatures of the gases released in mixture fuel, secondly measured the temperature of the mixture fuel to be found in the combustion chamber, the third one measured temperature of cooling water that used to cooling the combustion chamber, the exhaust analyser termed Spectrometry Gas Analyzer Instrument (SGAI). It measures the gases included in CO_x and NO_x.

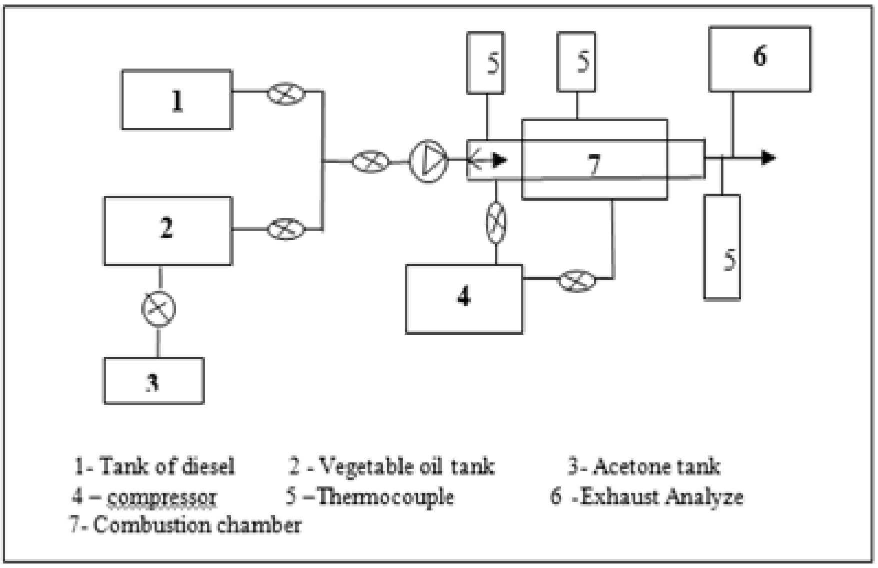

Figure (1): Experimental Setup.

Results and Discussion

Experimental results of fuel mixture combustion include VO that has different percentage of acetone, as it is shown in Fig. 2. These experiments were carried out by the author in the laboratory while working as a lecturer at the Technical College of K/Younis, in early 2009. Hence, the research methodology adopted in this study adopts quantitative methods, namely experiments based laboratory.

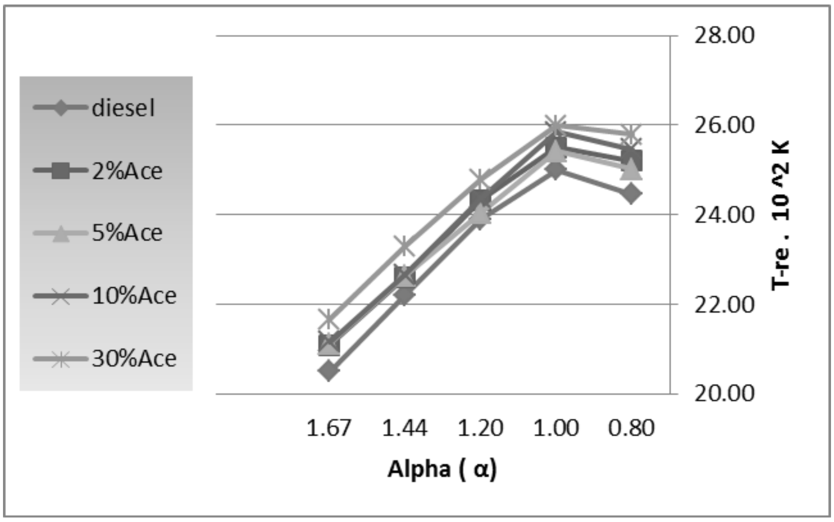

Figure (2): Combustion temperatures of VO with different per cent of acetone with Alpha variables. Alpha: coefficient incompletion air**.**

$$\alpha = \frac{Gair}{G_{fuel} \cdot a_f} \text{---------}(1)$$

Ratio consumption fuel-air

$$g_f = \frac{G_{fuel}}{G_{air}} \text{-----------}(2)$$

$$\alpha = \frac{1}{g_f \cdot a_f} \text{----------}(3)$$

G $_{air}$: mass air **G** $_{fuel}$: mass fuel and $\mathbf{a_f}$ **:** modulus depend on fuel kind,

$\mathbf{a_f}$ = 15" the amount of air in kg needed to complete burning of 1kg diesel like fuel" (Musalam, 2004).

The results outlined in Fig.2 for the first mixture fuel show that VO is comprised of different percentage of acetone in comparison to heat efficiency of the diesel. The results obtained through the experiments also show that adding acetone to VO at the percentage between 2% and

10% enables obtaining the thermal property, as it is the case in diesel heating property. When Coefficient Alpha is near α = 1, a high level of fuel combustion temperature follows. Experimental results also show that adding 30% of Acetone to VO has heat efficiency higher than that included in diesel property (Fig. 2). Nevertheless, the results related to CO_2 are similar to diesel. As shown in Fig. 3, the quantity related to CO_2 sharply contrasts the percentage of acetone included in VO – such relation reminds us of that embodied in diesel. However, one problem lies in that the addition of acetone that reaches higher than 10% in VO could cause damage to the engine.

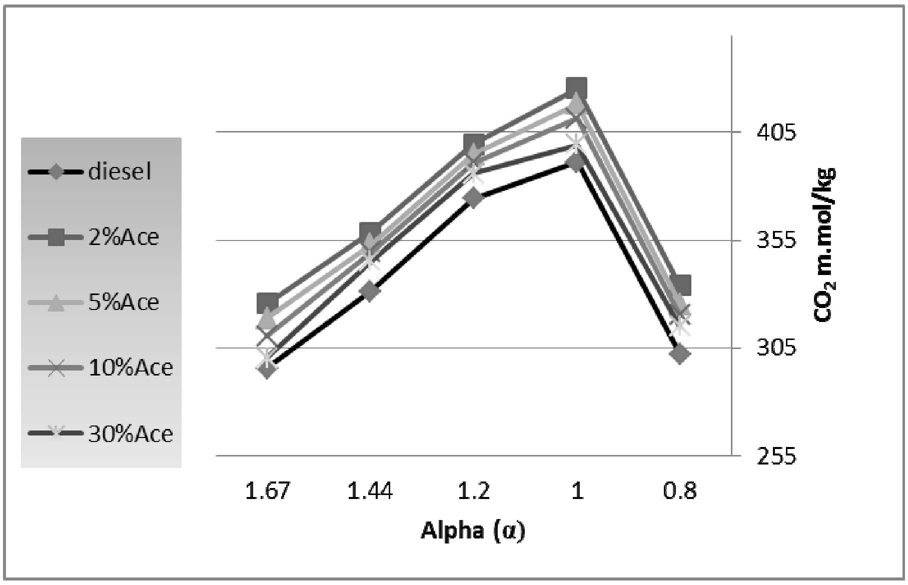

Figure (3): CO_2 emission from combustion of VO in different percentage of acetone versus Alpha variables.

Note that from the Fig. 3 we can obtain the minimum amount of CO_2 emitted at α=0.8 and α=1.67 but the results obtained from Fig.2 indicate that the maximum heat efficiency was obtained at α=1 and α=0.8 so the less CO_2 emission is possible when adjusting the engine at α=0.8 with acceptable heat efficiency, showing different rates of the acetone included in VO.

The below second experiment (VO and different percentages of diesel) indicates that the combustion process follows different percentages by adding VO to diesel. This experiment aims at producing the second mixture fuel. Fig. 4 shows that there is a comparison of mix VO in diesel coupled with diesel T (0%) in combustion chamber (Fig. 4).

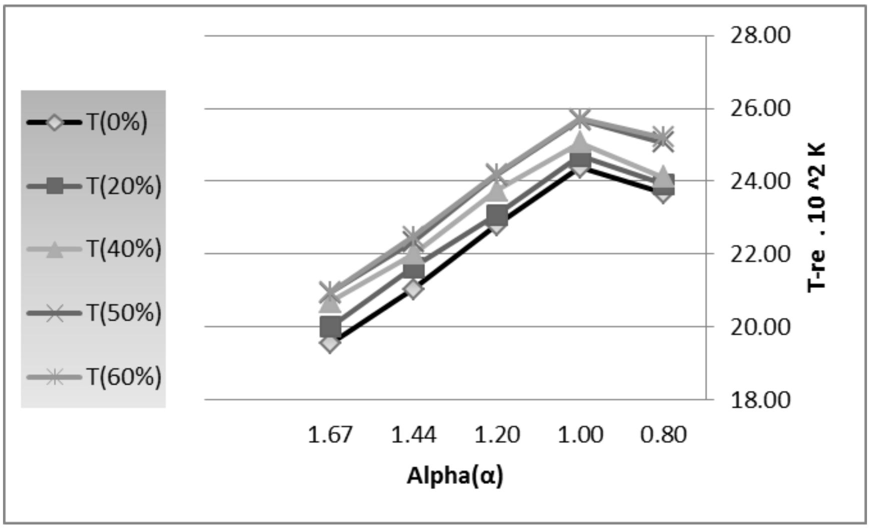

Figure (4): Combustion temperatures at different percentages of VO in diesel versus Alpha variables.

Collectively, the separate outcomes of the experiments suggest that the mixture of VO combined diesel is approximate to thermal property that ranges from T (0%) from 20% to 40% (VO in diesel). The percentages of 20% and 40% approach the thermal properties of diesel while noting that diesel acts as activator and solvent for VO.

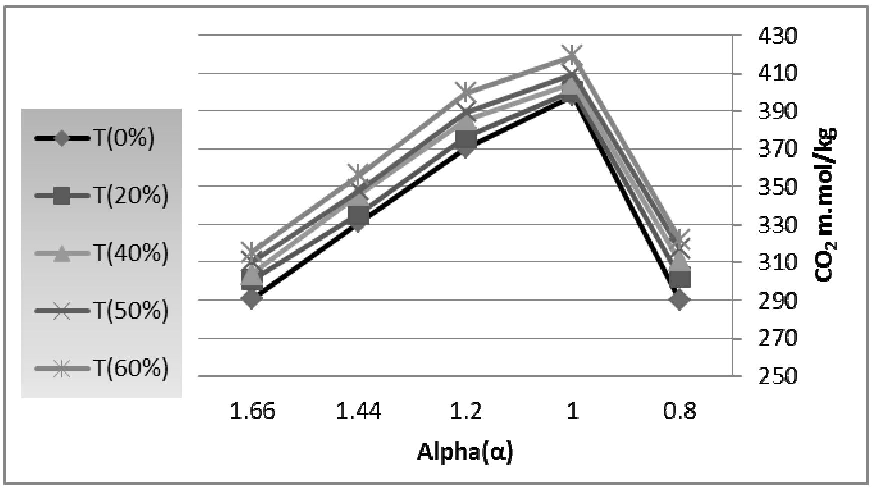

Figure (5): CO_2 included in products of the combustion measured at different VO percentages in diesel versus Alpha variables.

Fig. 5 indicates more percentage of VO in diesel, thereby increasing the rate of CO_2 in the gas resulted from the combustion, which increases the percentage of pollution resulted from burned compound. However, when coefficient Alpha is set at 0.8, the percentage of pollution is due to be less than the other alpha.

Fig. 6 shows experimental results that have been outlined in table 2. Accordingly, the mix combustion contains 80% VO and 20% diesel in conjunction with different acetone percentages; 80% VO in the mixture is selected. Owing to the economic factor and the percentage of diesel at 20% was sufficient enough to minimise the viscosity of VO while noting that diesel acts as activator. This experiment aims at producing the third fuel mixture. In comparison, working mixture, diesel and VO leads to the below results, as shown in Table 2.

Table (2): Combustion temperatures and gas emission of the third mixture at different α-values.

Fuel/Alpha		0.8	1	1.2	1.44	1.67
VO	T-re .10^2 K	24.34	24.54	23.50	21.84	20.31
	CO_2 m.mol\Kg	373	473	437	357	325
	NO_x m.mol\Kg	0.346	9.781	30.6	46.48	55.2
diesel	T-re 10^2 K	25.1	25.44	24.19	22.61	20.5
	CO_2 m.mol\Kg	300.05	390.97	373.18	330.96	292.6
	NO_x m.mol\Kg	0.121	7.94	28.4	43.4	50.9
5%Ac+mix	T-re .10^2 K	24.58	25.22	23.79	22.46	20.39
	CO_2 m.mol\Kg	305.46	400.61	380.94	336.76	302.91
	NO_x m.mol\Kg	0.172	8.221	29.331	46.21	54.32
10%Ac+mix	T-re .10^2 K	25.25	25.54	24.49	23.11	21.34
	CO_2 m.mol\Kg	318.05	408.87	389.61	347.67	308.85
	NO_x m.mol\Kg	0.253	9.471	30.481	46.238	54.44
20%Ac+mix	T-re .10^2 K	25.59	25.95	24.52	22.61	21.11
	CO_2 m.mol\Kg	322.07	409.39	390.88	349.42	310.65

…continue table (2)

Fuel/Alpha		**0.8**	**1**	**1.2**	**1.44**	**1.67**
	NO_x m.mol\Kg	0.293	9.542	30.53	46.33	54.73
30%Ac+mix	T-re .10^2 K	25.71	26.4	24.91	23.31	21.32
	CO_2 m.mol\Kg	324.88	414.89	392.07	351.07	312.36
	NO_x m.mol\Kg	0.341	9.822	30.631	46.452	54.998
35%Ac+mix	T-re .10^2 K	26.13	26.59	25.22	23.52	21.02
	CO_2 m.mol\Kg	323.18	409.44	386.29	346.01	307.91
	NO_x m.mol\Kg	0.3313	9.422	30.732	46.554	55.291

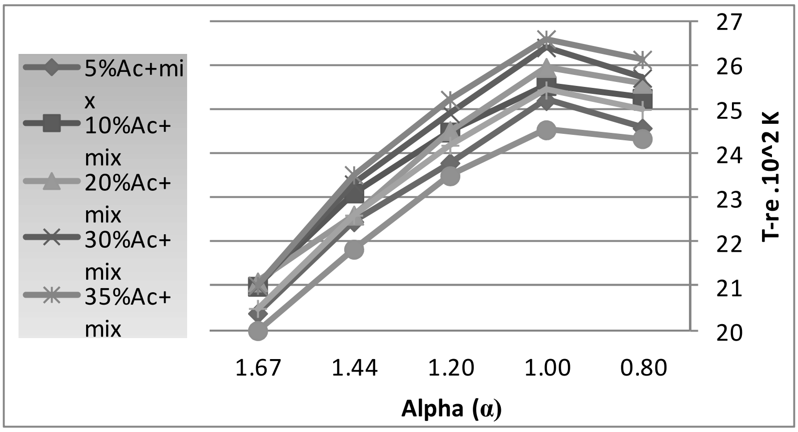

Figure (6): Combustion temperatures of a mixture fuel measured at different percentages by adding both acetone to 20% diesel and 80% to VO versus Alpha variables values.

Results, as shown in Fig. 6, show that adding acetone from 5% to10% to the mixture fuel makes its thermal property as similar as diesel at different Alpha values. Addition of Acetone to the mixture plays the role of activator and solvent, too.

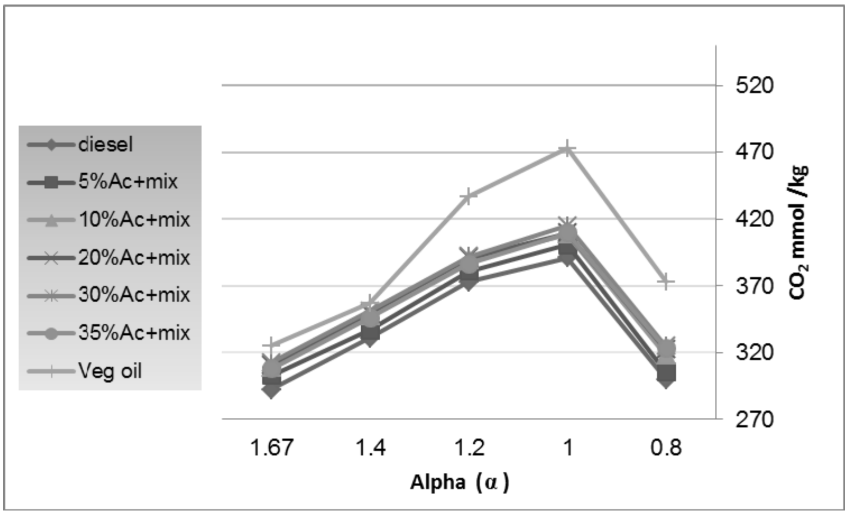

Figure (7): CO_2 included in products of the combustion at different fuels (adding both acetone to 20% diesel and 80% to VO) versus Alpha variables.

In accord to the previous graphic, an increase in the percentage of Acetone included in the compound would increase the rate of CO_2 included in the gas output of combustion. In turn, the latter rate increases the percentage of pollution resulted from the combustion compound so that the possible percentage of diesel appropriate in comparison to acetone rate ranges from 5% to 10% in the mixture fuel which is similar to the heat properties of diesel. At α=0.8 pollution is less than other values of alpha because high heat efficiency as shown in Fig. 7 and 8 is possible.

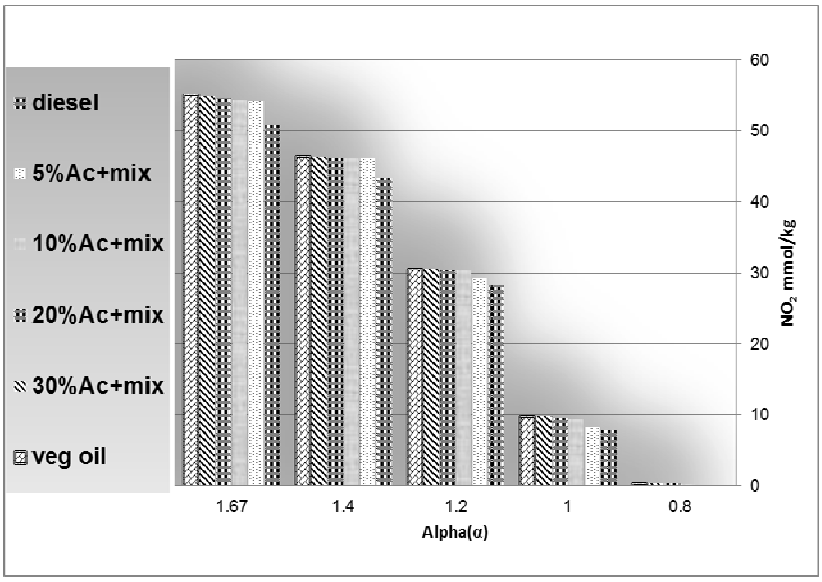

Figure (8): NO_2 included in products of the combustion measured at different mixture fuels (adding both acetone to 20% diesel and 80% to VO) versus Alpha variables.

The above graphic Fig. 8 points to the previous rates revealed in this study which ranges from 5% to 10% Acetone component in the mixture fuel. By adding acetone to 20% diesel and also to 80% VO the rate of NO_2 is reduced which is included in the gas resulted from the combustion. In addition, an increase in the proportion of Acetone raises the temperature of the combustion, thereby allowing malfunction in the engine**.** Having said the above, work associated with the recommended mixture is the third one when α=1 and Acetone ranges from 5% to 10%. Acetone is balanced between the emission of CO_2 and NO_2 as minimum as possible and also is reached through normal heat efficiency. Table 3 outlines the percentage necessary to minimise CO_2 and NO_2 emissions (with respect to pure VO); both are regarded as a function of acetone percentage.

Table (3): percentage of minimising of CO_2 and NO_2 emissions (with respect to pure VO) as a function of acetone percentage at α=1.

Fuel	mmol of NO_2/kg fuel	mmol of CO_2/kg fuel	% Minimized	
			CO_2	NO_2
VO	9.78	473	0	0
20% diesel and 80% Vo with 5%	8.2	401	15%	16%
20% diesel and 80% Vo with 10%	9.4	409	13.5 %	4%

All the above experiments were applied on diesel engines for certain operations hours. Therefore, despite the experiments operated effectively these lack enough time to present the final results. The latter will be followed in future research.

Conclusions

This study was set to test the hypothesis that a mixture fuel is a key largely replacing the already known diesel. As analysis in this study suggests, this mixture remains useful due to the followings:

- Alternative to diesel fuel is possible without any mechanical alterations being made to the engine itself;
- VO is a strong alternative to fuel diesel;
- A mixture of diesel coupled with VO is a possible alternative to diesel which could be used straight in the diesel engines;
- Diesel, such as a mixture fuel, could be gotten by adding solvents and activators to this mixture enabling the processes of heating treatment, thereby obtaining 100% performance, as it is the case in diesel;
- A thermal comparison made between VO coupled with a diesel combination and diesel was only useful in this study. This is because it enables effective diesel's performance without the need to apply any mechanical alteration to the engine itself;
- The right proportions of the compound are feasible through having access to the combustion temperatures, which is similar to the degree of combustion of diesel. In this vein, the percentage of pollution

resulted from the gas are the same as those in the diesel engines, particularly in relation to NO_2 and CO_2;

- The correct proportions of the compound works reduce the rates of NO_2, CO_2 in the gas emerged from the combustion process. These proportions enable completing the combustion of semi compound; and
- Adding solvents and activator enables an increase in the temperature. In turn, as this study suggests, these solvents exhaust the engine.
- The recommended mixture will be the third one, adding both acetone to 20% diesel and 80 % to VO, at α=1 and at 5% -10% acetone. The mixture balances the emission of CO_2 and NO_2 regarded as minimum as possible and also with a normal heat efficiency.

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Appendix 1

No	Abbreviation	Description
1	VO	Vegetable Oil
2	CWS	Mix Coal -water - Slurry
3	T-re	Temperature of burning the fuel
4	α	Ratio consumption of fuel-air
5	G_{air}	mass air
6	G_{fuel}	mass fuel
7	a_f	modulus depend upon the kind of fuel
8	0%	the percentage of VO in diesel fuel
9	20%	20% percentage of VO in diesel
10	DI	direct injection
11	CO_x	Carbon Oxides
12	NO_x	Nitrogen Oxides