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PRODUCTION AND PERFORMANCE EVALUATION OF BIODIESEL FROM PONGAMIA TREE OIL

Shabban, M. A[1] and H. M. Aly[2]
1 Researcher Agricultural Engineering Institute ARC
2 Researcher Forestry & wood technology Dept., Horticulture Research Institute, ARC

ABSTRACT

Energy is the prerequisite for modern civilization. Fossil fuel is still the main source of energy. But the endless consumption of fossil fuel has brought its reserve about to an end. As a result, spiraling demand and diminishing supply. Therefore, researchers are seeking for alternative and cost effective fuels to meet the human demands.

Experiments have been performed on a four strokes, two cylinder, direct injection, and naturally aspirated Diesel engine when operating on 10%, 20%, 30% and 40% blends with Diesel fuel. The purpose of this research is to test the effects of pongamia oil biodiesel inclusion in Diesel engine on power, specific fuel consumption (SFC), thermal efficiency, emission composition changes and exhausts temperature. At a higher speed of 1800 rpm, the (SFC) of the fully loaded engine for the B20 blend is the same as that for Diesel fuel, whereas B30 suggest the (SFC) is higher by 11.65%. The (SFC) of blend B10 appeared to be the same as that of blend B20, both of them have lower (SFC) by 2.9 % compared to Diesel fuel. The fuel energy conversion efficiency depends actually on both the biodiesel inclusion percent in the Diesel fuel and the engine performance conditions. The results indicate that higher than 10 vol% of biodiesel in Diesel fuel reduces the fuel energy conversion efficiency for the biodiesel.

INTRODUCTION

Diesel engines have enormous uses such as automobiles, chips, structure equipment, irrigation pumps, farm power etc. that is why; consumption of diesel fuel is much higher than other gasoline fuels. Diesel engines are more efficient and cost-effective than other engines. As a result, it is very imperative to find alternative fuel to reduce global warming which is contributed by the combustion of petrol diesel. Biodiesel is non-toxic, biodegradable, produced from renewable sources and contributes a minimal amount of net greenhouse gases, such as CO, CO_2, SO_2 and HC emissions to the atmosphere. *Pongamia pinnata* is a promising tree for biodiesel production it is fast-growing, multipurpose and nitrogen-fixing tree. It is regarded as very tolerant of saline conditions, drought and alkalinity, seeds contain non-edible oil, cattle and goats eat its leaves. Branches are commonly used as fuel wood.

Although biodiesel can be produced from a variety of vegetable oils, the biggest challenges remain that the vegetable oil should not be edible oil, should be cheap and its supply should be unlimited to the manufacturers. Hence in this study we have tried to explore the possibility of using a non-edible vegetable oil from Pongamia pinnata for biodiesel production with less energy input. Pongamia tree has been reported to grow easily without much care, because it is nitrogen fixing, can survive draught and is fast-growing (5 m through 5-7 years). About 30-40% oil can be extracted from dried ripe seeds (Scott, et al. 2008). Pongamia (Karanja) oil contains palmitic, oleic, stearic and linoleic acid mostly along with small amount of other long chain fatty acids and has a high acid number of 2.5 (Birajdar et al. 2011) calculated average molecular weight 892.7 and although some researchers produce biodiesel from Pongamia oil has been reported (Meher and Naik 2004), no literature is available reporting tryst to minimize reaction temperature and time by optimizing reaction parameters.

Pongamia seeds can be grown in non-fertile land and waste lands. The use of non-edible oil gave the best way to reduce the production cost of biodiesel. Also the processed vegetable oil can be used in any existing engine without any modification (Surendra et, al. 2008; Senthil et al., 2001; and Senthil et al., 2003). Biodiesel is usually produced by the transesterification of vegetable oil or animal fats with methanol or ethanol (Konthe, 2002; Konthe, 2006).This source of diesel is attracted considerable attention during the past decade as a renewable, biodegradable, eco-friendly and non-toxic fuel. Several processes have been developed for producing biodiesel. Methyl esters (biodiesel) are a clean burning fuel with no sulfur emission. Although its heat of combustion is slightly lower than that of diesel fuel, there is no need to modify the engine and there is no loss in efficiency (Shrivastava and Prasad, 2000).

Pongamia grows about 15-20 meters in height with a large canopy which widely spreads. The leaves are soft, shiny burgundy in early summer and mature to a glossy, deep green as the season progresses. Flowering starts in general after 4-5 years. It is semi-deciduous, drought resistant and nitrogen fixing leguminous tree. Cropping of pods and single almond sized seeds can occur by 4 to 6 years and yields 9 to 90 kg of seeds. The yield potential per hectare is 900 to 9000 Kg/ha. Pongamia oil has got a potential of 135000 million tons per annum and only 6% is being utilized. The tree is well suited to intense heat and sunlight and its dense network of lateral roots and its thick long tap roots make it drought tolerant.

Uses: The total Pongamia tree has got excellent medicinal properties.

Wood: wood is susceptible to insect attack, and is not considered as quality timber. It can be used in agricultural tools and combs.

Oil: Oil color is yellow – orange to brown. Mechanical expeller can produce about 24% oil yield. It has bitter test and disagreeable aroma, It is non-edible oil. This oil can be used for cooking and lightning.

Leaves: Leaves can be used for anthelmintic, digestive, and laxative, for inflammations, piles and wounds. Their juice is used for colds, coughs, diarrhea, dyspepsia, flatulence, gonorrhea, and leprosy. The fresh leaves are used for feeding cattle, sheep and goats in arid regions.

Cake: It constitutes flavonoids, uranoflavonoids, and furan derivatives, and treating skin diseases. It can be used as fertilizer, pesticide and organic farming.

Seed shells: It can be used as combustibles.

Kernel: It is used for medicinal and oil extraction.

Root and bark: They are used for abdominal enlargement, ascites, biliousness, eye diseases, skin, and vagina itch, splenomegaly, tumors, ulcersand wounds as cleaning gums, teeth and ulcers.

Fruit: It can be used as green manure, biogas production and combustibles.

Pongamia trees grow on most soil types stony, sandy, gravely and clayey. It does not grow well in dry sands Yaliwal et, al. 2010. Pongamia oil is very thick high to be used instead of diesel fuel. Viscosity would be reduced by the transesterification process. (Kumar et, al.2013). Pongamia oil is economic as biodiesel because it is non-edible and for its less consumption in domestic purposes. Biodiesel decreases the emissions of hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM) and sulphur dioxide (SO_2) (Ghosha et al., 2008).

Its flowers are pink, light purple or white. Pods are elliptical, 3 to 6 cm long and 2 to 3 cm wide, thick walled and usually contain a single seed sometimes double seeds. Seeds are 10 to 20 mm long, fig oblong and light brown color (Sayyed et al., 2013).

(Kanji and Pravin, 2013) indicated that Pongamia oil has better performance and emission characteristics than Mahua, Sesame and Kusum Biodiesels.

This paper estimates the feasibility of producing biodiesel from non-edible oil of *Pongamia pinnata* by transesterification of the crude oil with methanol in the presence of KOH as catalyst. Various properties, performance and emission of Pongamia Pinnata biodiesel have been studied at 10, 20, 30 and 40 % to compare with diesel fuel at varying speeds and Loads.

MATERIALS AND METHODS

The Pongamia seeds are collected from Antoniades Botanical Garden Alexandria Egypt. The seeds are selected, cleaned, and dried at temperature of 105 ^{O}C for 30 minutes then taken for oil extraction.

Extraction of oil: The oil extracted by mechanical expeller and by chemical extraction method. Mechanical extraction method-(Single chamber oil Expeller). This method requires extra time to recover oil and the yield is lower as compared to chemical (Soxhelt) method.

Soxhelt Extraction Method- (Solvent extraction method): seeds were grinded twice and 50 gm was taken and a thimble was made. The soxhelt apparatus was set up and 300 ml of hexane was added to thimble from above. Mechanical and chemical extraction oil have been done at City of Scientific Research and Technological Applications Burg–El Arab Alexandria suburb.

Working of apparatus: Soxhlet extraction method is only required when the compound has a limited solubility in a solvent and the impurity is insoluble in that solvent. Normally a solid material is placed inside a thimble made from thick filter paper, which is loaded into the main chamber of the Soxhlet extractor. The Soxhlet extractor is placed onto a flask containing the extraction solvent. The Soxhlet is equipped with a condenser. The Soxhlet is heated to reflux. The solvent vapor travels up a distillation arm and floods into the chamber housing of the thimble. The condenser ensures that any solvent vapors cools and drips back down into the chamber housing of the solid material. The chamber containing the solid materials slowly filled with warm solvent. Some of the desired compounds get dissolved in the warm solvent. When Soxhlet chamber is almost full, the chamber is automatically emptied by a siphon side arm, with the running back down to the distillation flask.

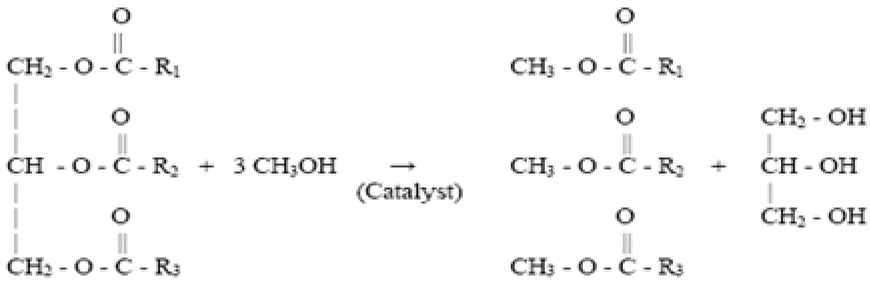
This cycle is repeated several times within 8 hours. During each cycle, a portion of the non- volatile 18 compound dissolves in the solvent. After many cycles the compound is concentrated in the distillation flask. After the extraction has finished, the solvent is removed, typically by means of a rotary evaporator at 40-50 ^{o}C, yielding extracted oil. The non-soluble portion of the extracted solid is removed separately.

Determining of fatty acid composition

Gas chromatography has been used to determine the fatty acid composition percentage of Pongamia oil and its physicochemical properties determined as per BIS method (Arun K.V. et al., 2013). Pongamia oil contains some different types of fatty acids. Different fractions of each type of fatty acids influence on the fuel properties.

Production of biodiesel through Transesterification process:

Vegetable oil is not suitable direct replacements for diesel fuel in engines; however, it is possible to reduce the viscosity of vegetable oil, improve the physical properties through transestrification process. Vegetable oil has inappropriate physio-chemical properties such as longer molecule chains, lower vapor pressures, higher viscosities and higher flash points. These features cause poor atomization, poor vapor–air mixing, low pressure, and incomplete combustion and engine deposits. Two major inappropriate properties that influence the production process are water content and FFA (free fatty acid) present in the oil. Water content of Pongamia oil is about 10.2% and FFA content is about 15.62% (equivalent to 31.24 mg of KOH/g sample) depending on the source (Khayoon, et al., 2012). The trans-esterification process is the reaction of triglyceride (fat/oil) with alcohol in the presence of catalyst to form biodiesel and glycerol. The trans-esterification reaction is used to reduce the high viscosity of triglycerides. Scheme R1, R2, and R3 in this diagram represent long carbon chains that are too lengthy to include in the diagram.



triglyceride methanol mixture of fatty esters glycerol

To prepare biodiesel from pongamia crude oil first methyl alcohol was put in the pre-mix tank then potassium hydroxide was added and mixed together to form potassium methoxide, simultaneously oil was heated in a processor tank. When temperature of oil reached to 60 ^{o}C then potassium methoxide was added and mixed into the processor with oil for two hours. The mixture was allowed to settle for 8 hours. Methyl ester was separated and washed (dry washing) to remove traces. The final good quality biodiesel was subjected for chemical analysis at Petroleum Research Institute, and the results were compared to the American Standard for Biodiesel Testing Method (ASTM D 6751) and European Norm (EN 14214). These methods are shown in Tables (1).

Table (1): Standard tests for fuel properties

Test	ASTM test No.
Viscosity, mm^2/s	D445
Distillation temperature, °C	D86
Cloud point, °C	D2500
Pour point, °C	D97
Flash point, °C	D93
Water & sediment, % by volume	D1796
Carbon residue @, 10% residuum	D524
Ash by weight, %	D482
Sulfur by weight, %	D129
Sulfur & copper corrosion	D130
Cetane No.	D613
APT gravity	D287

Pongamia Pinata oil methyl ester has been investigated at different percent as additive to diesel fuel in a 4-stroke diesel engine (two cylinder Helwan 35-IMT) with maximum power of 26.12 kW at 1800 rpm at Tractor Test Station in Sabahia Alexandria during 2015. The engine has a bore of 105 mm, a stroke of 125 mm, a compression ratio of 1:16, and engine rated speed 1800 rpm. Engine speed was controlled by a throttle positioner.

It is very important to know the physio-chemical properties of the biofuel being burned and to compare it with the basis fuel named in the performance specifications.

All four tested percent of biodiesel 10, 20, 30 and 40 % dissolved readily in diesel fuel. The fuel mixture was completely homogeneous with no sediment formation. Engine in this study performed well when fueled with biodiesel blends and no related fuel problems were observed during tests. No engine or fueling system modifications were made on the tractor to run on biodiesel. The engine has been left running for 8 continuous hours with no engine problems.

Hydraulic dynamometer:

The engine power was determined using a hydraulic dynamometer. The tractor PTO shaft was coupled to the dynamometer for applying loads according to the ASAE Standard of tractor PTO performance at rated engine speed as shown in fig. (1).

Some characteristics for hydraulic dynamometer are listed in Table (2). Torque was measured at rated engine speed and its power was calculated from the following equation:

$$P = \frac{2 \times \pi \times N \times T}{C}$$

Where:

P = Power, kW

N = Speed of PTO shaft, rpm

T = Torque, N.m.

C = Conversion constant = 1000

Figure 1: The tractor PTO was coupled to the dynamometer for applying loads

Table (2): Technical specifications of the hydraulic dynamometer

Model	**AW 2-300**
Maximum power	220 kW
Maximum torque	1360 N.m
Maximum RPM	3500
Constant torque number	10

Thermal efficiency was determined from the following formula.

$$Thermal\ Effiecieny = \frac{BHP\ x\ 60\ x\ 60\ x\ 75}{F.C\ x\ C.V\ x\ 427}\ x\ 100$$

Where:

BHP = brake horsepower
F.C = fuel consumption, kg/h
C.V = Calorific value of fuel, kCal/kg
427 = Thermal equivalent of fuel.

Fuel consumption meter:

A fuel consumption apparatus was used to measure the amount of fuel consumed in each test as shown in fig. (2). The apparatus is connected to the engine fuel system line in such a way that the engine consumes all fuel passing through the apparatus. To measure fuel consumption, tank was filled with a certain amount of fuel and bleeds the air by opening tap. After testing the tractor by fuel the tap is closed and the engine starts to draw fuel from the glass bulb having capacity of 37 cm^3. The elapsed time to consume this amount of fuel was recorded. To prepare B20 (20% biodiesel to 80% diesel) 400 cm^3 of biodiesel was added to 1600 cm^3 of diesel fuel and put in additional fuel tank. After obtained the data of B20 fuel the engine was shut off and the fuel was bled from the fuel system. The engine was run for a long time to remove all residual of the previous fuel. The engine fuel filter was replaced with a new one for each biodiesel percentage (10, 20, 30 and 40%).

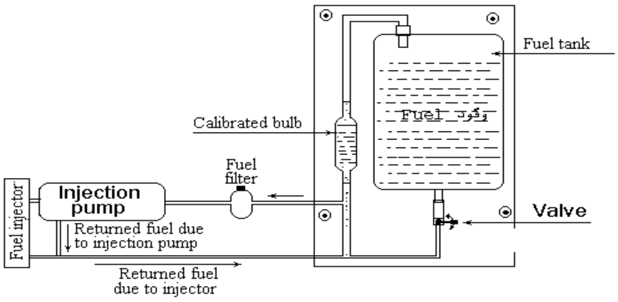


Fig. (2): Local manufactured fuel consumption meter

Gas analyzer:

Exhaust measurements for carbon monoxide CO, nitrous oxides NOx, carbon dioxide CO_2, oxygen O_2 and exhaust temperature at different biodiesel percent were conducted using a stack analyzer. The emission stack measurement system consisted of a probe to sample gaseous emissions from the exhaust combustion effluents in the stack pipe connected to a direct reading combustion gas analyzer as illustrated in fig. (3).

Fig. (3): The exhaust gas analyzer

RESULTS AND DISCUSSION

Extracting oil from pongamia seeds were done by two different methods that are mechanical and chemical methods. The yield of extracted oil from Pongamia seeds is listed in table (3). It evidently showed that the yield percentage of soxhelt extraction (chemical method) was higher than that of mechanical method by 11.19 %.

Table-3 Percentage oil of ponagamia pinnata seeds

Extraction Method	Yield, %
Mechanical expeller	23.17
Soxhelt extraction	34.36

Chemical Composition of Pongamia Oil

The seeds of Pongamia contain 30 to 40 % oil, this oil is thick, reddish brown in color. Fatty acids composition of pongamia seeds oil has 20.6% saturated and 79.4% unsaturated long chain fatty acids. The major mono unsaturated fatty acid is oleic acid (51.59%), linoleic acid (16.64%) and palmatic acid (11.65%) which constitutes the total polyunsaturated fatty acids. Low molecular weight fatty acids such as lauric and capric acids were in very small amount (0.1% each). The tested fuel oil contains up to 7 different types of fatty acids. Different type of fatty acid present in pongamia oil influence some of the properties of the fuel. Linoleic (C_{18}:2) and oleic (C_{18}:0) polyunsaturated acids constituted the highest fatty acid content in the oil. Percentage of fatty acids in Pongamia Pinnata crude oil are listed in Table (4).

Table (4): Fatty acid composition of pongamia pinnata crude oil

Fatty acid of Pongamia oil	Molecular formula	Percentage	Stracture
Palmitic Acid	$C_{16}H_{32}O_2$	11.65	$CH_3(CH_2)_{14}COOH$
Stearic Acid	$C_{18}H_{36}O_2$	7.50	$CH_3(CH_2)_{16}COOH$
Oleic Acid	$C_{18}H_{34}O_2$	51.59	$CH_3\ (CH_2)_{14}(CH=CH)COOH$
Linoleic Acid	$C_{18}H_{32}O_2$	16.64	$CH_3(CH_2)_{12}(CH=CH)2COOH$
Eicosanoic Acid	$C_{20}H_{40}O_2$	1.35	$CH_3(CH_2)_{18}COOH$
Dosocasnoic Acid	$C_{22}H_{44}O_2$	4.45	$CH_3(CH_2)_{20}COOH$
Tetracosanoic Acid	$C_{24}H_{48}O_2$	1.09	$CH_3(CH_2)_{22}COOH$

The degree of saturation of the fatty acid governs the quantity of energy contained within. The presence of double bonds in unsaturated fat lowers the energy of the molecule, with respect to a saturated fat, which has only single bonds. The Pongamia oil has disagreeable odor and bitter taste. The chemical extraction method gives good quality oil than mechanical methods. The iodine value is a measurement of the unsaturation of fats and oils. Higher iodine value indicated that higher unsaturation of fats and oil (Kyriakidis and Katsiloulis, 2000; Konthe, 2002). The fatty acids may be saturated, monounsaturated, or polyunsaturated, Length of carbon chains and number of double bonds in the fuel molecules affect low temperature suitability, spray formation and carbon residue (Corinna, 1998).

Physical-chemical Properties of Pongamia pinnata biodiesel

The parameters were examined according to the ASTM specification for diesel fuel. Some of the most important properties include the following:

Calorific value: The energy release of biodiesel is slightly lower than that of petroleum diesel since it contains slightly lower calorific value. Generally, heat of combustion increases with increased chain length of fatty acids, and increases with unsaturation (Goering, et al., 1982; Anastasiosm, et al., 1998; Hazlett and Hall, 1985).

Cetane No.: Cetane no. for biodiesel was close to that of petroleum diesel. Cetane number rates the ignition properties of diesel fuels (Ullman, et al., 1990; Ali, et al., 1995). It's a measure of a fuel's willingness to ignite when it gets compressed. This factor influences ease of starting, duration of white smoking after start-up, drivability before warm-up and intensity of engine knock at idle. A general guideline for minimum cetane index is 40 for all engines.

Cloud Point: This is the temperature at which a cloud or haze appears in the fuel.

Pour Point: A fuel's pour point should be at least 6°C (10°F) below the lowest ambient temperature that is required for engine start-up and for engine operation (Tyson, 2001; Goering, et al., 1982). The pour point of biodiesel was higher than diesel fuel.

Viscosity: The main problem in vegetable oil fuels is its viscosity, which is several folds higher for diesel fuel. 4.66 mm^2/sec for 100% biodiesel compared to diesel fuel (2.7mm^2/sec) and ASTM specifications (1.9-6 mm^2/sec).

Flash Point: The flash point of a fuel is defined as the temperature at which it will ignite when exposed to a spark or flame (Tyson, 2001). Testing has shown the flash point of biodiesel blends increases as the percentage of biodiesel increases.

Water Content**:** Analysis revealed acceptable limits and below the recommended specifications.

Ash and carbon residues: An Ash and carbon residue of biodiesel was below specifications.

Sulfur: The percentage of sulfur that is in the fuel was below the recommended standard of 0.5% max.

Finally it can be seen that most properties were within the recommended level ASTM specifications except cetane no.

Fuel structure and characteristics have been shown to have great influence on engine performance and emission behavior (Zumdahl, 1995; Goeringm et al., 1982). Ordinary diesel fuel is a mixture of hydrocarbon molecules of differing lengths and structures. These molecules do not contain oxygen atoms. They may have double-bonded carbons that cause the chains to bend. The characteristics of the hydrocarbons affect how they burn. Vegetable oils, on the other hand, are mixtures of fatty acids molecules that contain carbon, hydrogen, and oxygen atoms (Table 5).

Experiments were performed to determine the effect of biodiesel percent on engine power, specific fuel consumption, exhaust temperature, thermal efficiency and pollutant emission.

Table (5): Properties of methyl-ester Pongamia oil compared to American and European Standard

parameter	bio-diesel	En 14214/ASTM limits
Density, at 15 ^oC	0.893	0.860-0.900
Viscosity,mm^2/s at 40 ^oC	4.66	3.5-5.0
Water Content, %	0.038	0.500
Cetane number	50	51
Pour point, ^oC	3.0	NS
Flash Point, ^oC	174	120 min
Ash, %	0.07	0.02
Heating value, MJL^{-1}	33.5	
Free Glycerin wt., %	0.0064	0.02
Total Glycerin wt., %	0.082	0.240
Phosphorus, mg/kg	0.04	< 4-10
Monoglyceride Content, wt.%	2.63	<0.8
Diglyceride Content, wt. %	0.78	<0.2
Triglyceride Content, wt.%	0.06	<0.2

An important property of biodiesel is its oxygen content about 10% which is usually not contained in diesel fuel. Moreover, they are non-toxic has higher biodegradability and contains almost no sulphur (Rambabu et al., 2012). Bio-fuels have some advantages over petroleum fuels, such as the reduction CO and CO_2 emissions and well antiknock performance, which allow the use of higher compression ratio of engines. Also, self -ignition temperature and flashing point of bio-fuel are higher than those of petroleum fuels. (Jalpesh and Agarwal, 2012). A comparison of all blends with diesel fuel showed that this oil derived bio-fuel would not diminish the quality of a petroleum fuel to which it was added.

The engine performance test:

The engine performance test at rated engine speed 1800 rpm for fuel blends of 10, 20, 30 and 40% are shown that fortunately, the increase in power of diesel than bio-diesel is not greater than 5%. These results give proper engine performance of bio-diesel comparable to diesel fuel. Torque values were 100.58, 99.63, 96.125 and 83.81 N.m for B10, B20, B30 and B40 respectively as compared with 101.7 N.m for diesel fuel while, power values were 18.95, 18.77, 18.11 and 15.79 kW for 10, 20, 30 and 40% respectively as compared with 19.16 kW for diesel fuel. Both power and torque decrease with increase biodiesel ratio as revealed in Fig. (4). Because of the lower calorific value of biodiesel compared to diesel fuel, they show higher fuel consumption. (Ghassam et al., 2007).

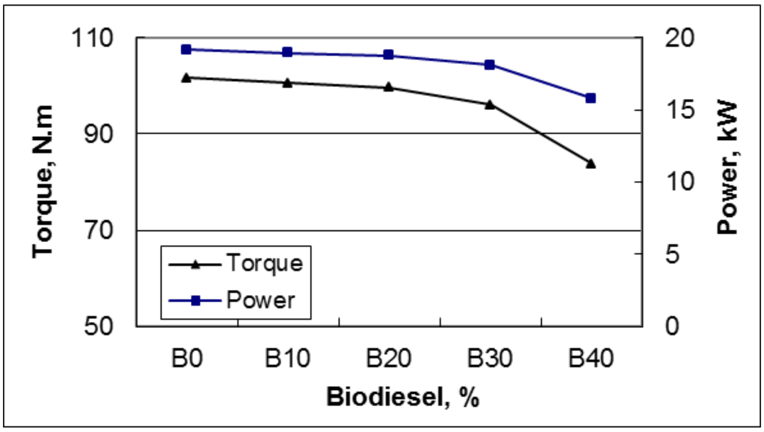


Fig. (4): Effect of different biodiesel percentage on torque and power at rated engine speed 1800 rpm

Specific fuel consumption

As shown in Fig. (5) it can be seen that the engine's specific fuel consumption (SFC) when using blended fuel is higher (195.25 to 303.99 Cm^3/kW.h) than that when operating on diesel alone (182.67 Cm^3/kW.h).A general trend of decrease in diesel fuel consumption with deceleration is clear over the whole biodiesel blends. Specific fuel consumption for biodiesel is lower than specific fuel consumption of diesel fuel that may be referring to the lower calorific value of biodiesel by 12.22 %. The higher fuel consumption of bio-diesel can be related primarily to the lower-in average by 12.22 % net heating value of biodiesel. However, this is probably not the only reason. The lower SFC can be related, reasonably, to the amounts of oxygen present in biodiesel (about 11 %). Fuel based oxygen, because of its indigenous property, accelerates reactions from within the extremely fuel rich spray patterns themselves, leading to more complete combustion.

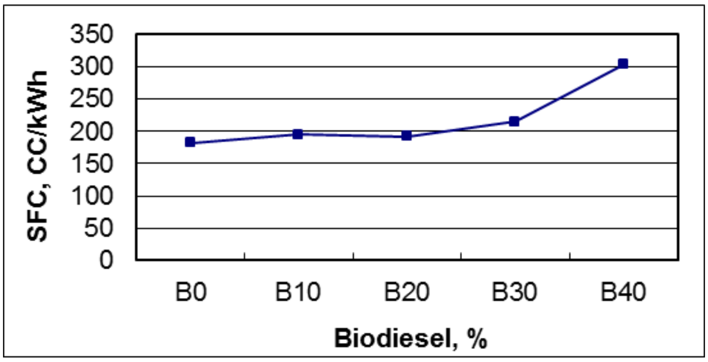


Fig. (5): Effect of bio-diesel percentage on specific fuel consumption

(Zubik, et al., 1984) indicated that the performance, combustion and exhaust emissions of diesel fuel and a blend of 25 % sunflower oil methyl ester all performed satisfactorily in a direct injection diesel engine. Several research works (Gretchen, 2000; Marshall et al., 1995; Chang et al., 1996) indicated that a 20-percent biodiesel blend delivers power, torque and fuel economy (virtually the same mile per gallon rating) comparable to petroleum diesel.

Thermal efficiency

According to (Canakci and Van Gerpan, 1999) thermal efficiency is defined as actual brake work per cycle divided by the amount of fuel chemical energy as indicated by lower heating value of fuel. Results indicated that the thermal efficiency with biodiesel and its blends was found to be slightly lower than that of diesel fuel under tested load conditions. Thermal efficiencies of engine, operating with biodiesel mode were 30.13, 28.33, 26.91 and 25.3% at 10, 20, 30 and 40% respectively compared to 31.72 % for diesel fuel as revealed in Fig. (6).

Emissions

Exhaust temperature

The obtained results at rated engine speed of 1800 rpm showed that the diesel fuel operation recorded higher exhaust temperatures than all biodiesel blends as shown in fig. (7). This was due to the higher relative density and lower energy density of Biodiesel. The net calorific value of the bio-diesel used is about 12.22 % lower than that of diesel fuel where the exhaust temperature served as an indicator of the combustion temperature relating to heat release, which is related to fuel calorific value that would be lower in the case of bio-diesel.

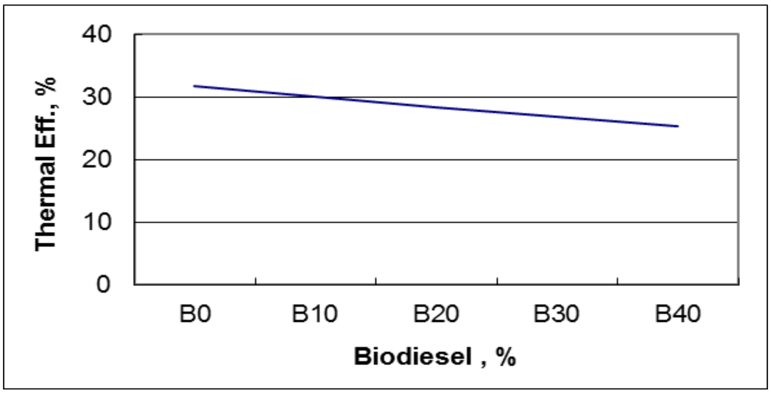


Fig. 6: Effect of methyl ester percentage on thermal efficiency

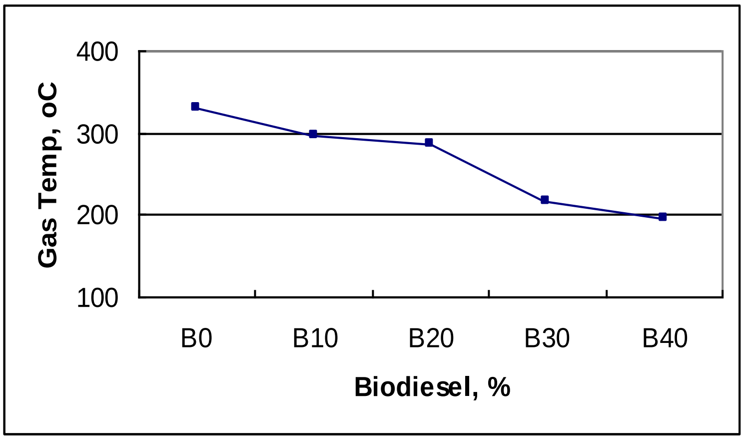


Fig. (7): Variation of exhaust temperature of diesel and bio-diesel fuels at different biodiesel percentage.

Since bio-diesel is free from sulfur so there is no results obtained from the emission device. SO_2 equal zero at all biodiesel percentage and for diesel fuel 57 ppm.

Carbon monoxide

Bio-diesel is an oxygenated fuel and leads to more complete combustion; there is a_marked reduction in CO emission, compared to diesel. The average level of CO was 559 ppm for diesel fuel compared to 308, 191, 187 and 203 ppm for 10, 20, 30 and 40% biodiesel respectively, as shown in fig. (8). Biodiesel reduced CO emissions mainly because it has higher oxygen O_2 content than diesel, which encourages more complete combustion. (Wang et al., 2000).

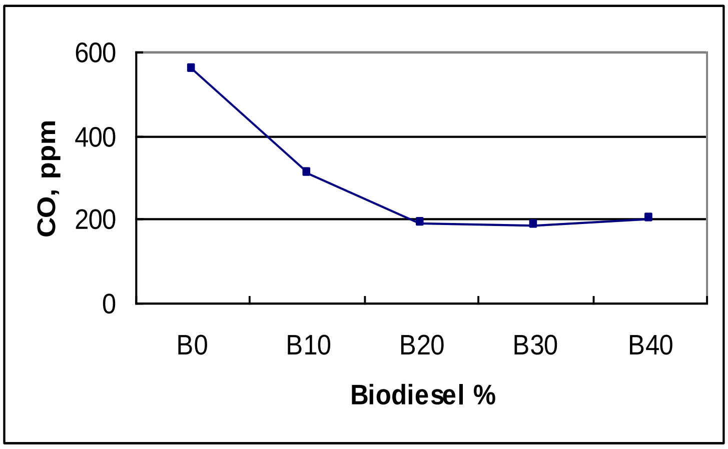


Fig. (8): Effect of diesel and biodiesel percentage on CO emission.

Oxygen

The average level of O_2 was 18.5 % for diesel fuel compared to 17, 16.6, 17.8 and 18.5 % for 10, 20, 30 and 40% biodiesel respectively, as shown in fig. (9).

Carbon dioxide

This is evident from the high combustion efficiency of biodiesel relative to diesel, the lower percentage of exhaust O_2 in the effluent which is mostly used in the combustion process and the higher percentage of CO_2 as a complete combustion product as illistrated in fig. (10).

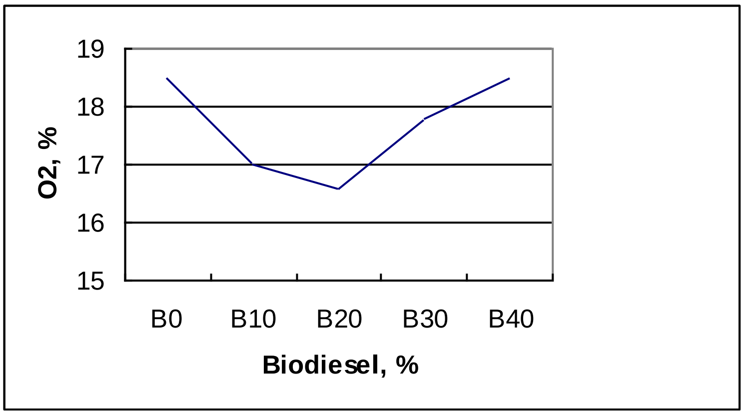


Fig. (9): Effect of diesel and biodiesel percentage on O_2 emission.

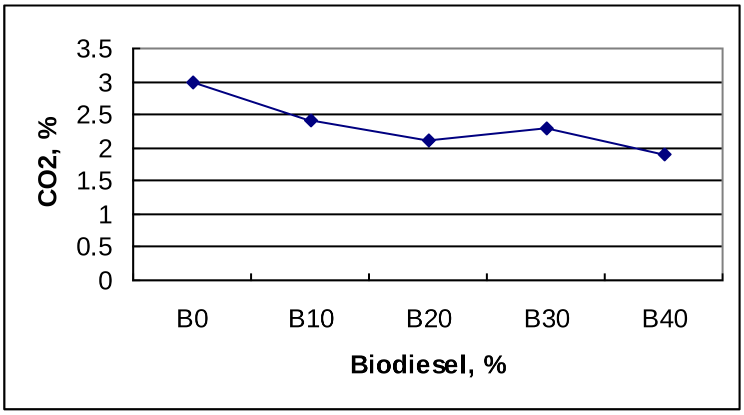


Fig. (10): Effect of diesel and biodiesel percentage on CO_2 emission.

Nitrogen oxides

The mechanism of NOx formation from atmospheric nitrogen has extensively been studied and it accepted that it is highly dependent upon temperature, due to the high activation energy needed for the reactions involved. Hence the most significant factor that causes NOx formation is high combustion temperatures. The emissions of NO and NO_2 firstly increase until the (air/fuel) ratio reach the theoretical value, and then decrease at higher loads. This is probably due to the increase in turbulence inside the cylinder, which may contribute to a faster combustion and to lower residence time of the species in the high temperature zones. Almost every bio-fuel produced higher amounts of NOx than conventional diesel. The formation of NOx depends on the combustion temperature and oxygen content in the mixing combustion product. Biodiesel blend fuel has a faster ignition ability, increase the combustion room temperature and pressure, which would finally stimulate the NOx formation, as shown in fig. (11).

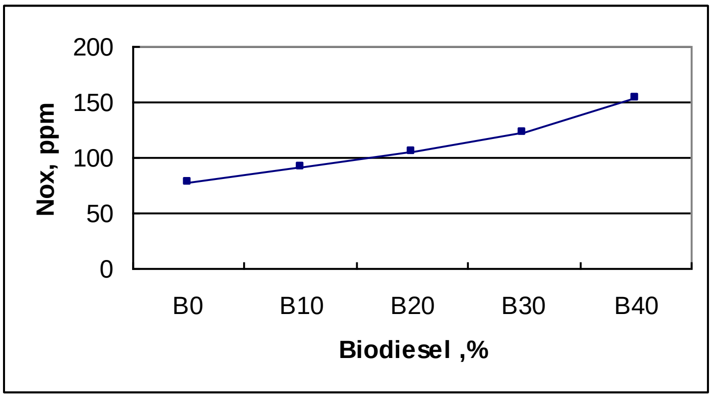


Fig. (11): Effect of diesel and biodiesel percentage on NOx emission.

CONCLUSION

A 26.12 kW diesel engine with Dynamometer was used to test *pongamia pinata* biodiesel and its blends and compared with conventional commercial diesel fuel.

The fuel properties of *pongamia pinata* biodiesel were found to be similar to the diesel fuel. Power values were 18.95, 18.77, 18.11 and 15.79 kW for 10, 20, 30 and 40% respectively compared to 19.16 kW for diesel fuel. Specific fuel consumption increased from 195.25, 191.8, 215.35 and 303.99 cm^3/kW.h for 10, 20, 30 and 40% biodiesel respectively compared to 182.67 cm^3/kW.h. Thermal efficiency for biodiesel and its blends was found to be slightly lower than that of diesel fuel under tested load conditions and there was no difference between the biodiesel and its blended fuel efficiencies. The exhaust gas temperature increased with increase amount of diesel. The carbon monoxide were 308, 191, 187 and 203 ppm at 10, 20, 30 and 40% biodiesel respectively compared to 559ppm for diesel fuel. SO_2 equal zero at all biodiesel percentage and for diesel fuel 57 ppm. The average level of O_2 was 18.5 % for diesel fuel compared to 17, 16.6, 17.8 and 18.5% at 10, 20, 30 and 40% biodiesel respectively. The NOx emissions from biodiesel were 92, 105, 123 and 154 ppm at 10, 20, 30 and 40% respectively, compared to 78 ppm for diesel.

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إنتاج وتقييم أداء البيوديزل الناتج من زيت شجرة البونجاميا

شعبان محمود أحمد[1] و هشام محمد على [2]

1 معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية

2قسم الأشجار الخشبية وتكنولوجيا الأخشاب – معهد بحوث البساتين – مركز البحوث الزراعية

الطاقة لها أهمية كبري في حياتنا ولازال الوقود السائل هو المصدر الرئيسي للطاقة. لكن الاستهلاك العالي للوقود السائل ادي الي قرب نضوبه ونتيجة لذلك تزايد الطلب على الوقود عن المتاح. لذا فإننا نبحث دائما عن البدائل لتقليل التكلفة وتغطية الاحتياجات من الطاقة. محركات الديزل هي الاكثر كفاءة والاقل في تكلفة التشغيل من المحركات الأخرى. لذا فان محركات الديزل لها استخدامات متعددة مثل السيارات، طلمبات الري، في الزراعة ...الخ. وهذا هو سبب زيادة استهلاك السولار عن البنزين. ايجاد الوقود البديل أصبح مهم في وقتنا الحالي وذلك على مستوي العالم وهذا يرجع ايضا الي المجهودات العديدة في تقليل ظاهرة الاحتباس الحراري والناتجة عن حرق المواد البترولية مثل السولار. بينما الوقود البديل مثل البيوديزل غير سام وقابل للتحلل وينتج من مصادر متجددة ويسهم في الحد من الاحتباس الحراري والانبعاثات الضارة في الجو مثل أول اكسيد الكربون وثاني اكسيد الكربون وثاني اكسيد الكبريت والهيدروكربون.

تعتبر البونجاميا شجرة واعدة لإنتاج الوقود الحيوي حيث أنها شجرة سريعة النمو ومتعددة الأغراض ومثبتة للنيتروجين الجوي. كما تعتبر شجرة متحملة جدا لظروف الملوحة والجفاف والقلوية. زيت البذور غير صالح للأكل، وأوراق الشجرة تعتبر علف للأبقار والماعز. والأفرع تستخدم عادة كوقود خشبي.

تم إجراء تجارب على أداء محرك ديزل رباعي الاشواط (2) اسطوانة مع خليط الوقود الحيوي بوقود الديزل بنسب 10 &20 & 30 & 40%. الغرض من هذا البحث هو اختبار تأثير الوقود الحيوي مع محرك ديزل على الاستهلاك النوعي للوقود والكفاءة الحرارية ونواتج العادم ودرجة حرارته. وعند أعلي سرعة دوران للمحرك وعند الحمل الكامل كانت قدرة المحرك 18.95 , 18,77 , 18,11 , 15,79 كيلو وات مقارنة 19,16 كيلو وات مع وقود الديزل. الاستهلاك النوعي للوقود الحيوي عند خليط 20 % مساوي الاستهلاك النوعي لوقود الديزل. بينما خليط 40 % وقود حيوي كان الاستهلاك النوعي أعلى بمقدار 11.65 % من الاستهلاك النوعي لوقود الديزل. الاستهلاك النوعي للوقود عند 10 % تقريبا مساوي للاستهلاك النوعي للوقود عند نسبة خلط 20 % وقود حيوي وهما لهم استهلاك نوعي للوقود منخفض بمقدار 2.9% مقارنة مع وقود الديزل. كفاءة طاقة الوقود تعتمد على نسبة الوقود الحيوي في وقود الديزل وظروف أداء المحرك. الكفاءة الحرارية للمحرك 30,13 , 28,33، 26.91 , 25,3 % عند 10, 20 , 30 , 40% خليط للبيوديزل مقارنة 31,72% مع وقود الديزل.

عند نسبة وقود حيوي أعلى من 10% (بالحجم) تنخفض كفاءة طاقة الوقود. الأكاسيد النيتروجينية تزداد بزيادة تركيز الوقود الحيوي مع وقود الديزل. عند أقصي حمل أعلي قيمة لأول اكسيد الكربون 559 ppm مع وقود الديزل وأقل قيمة 187 ppmعند خليط 30% وقود حيوي مع وقود الديزل. أفضل احتراق تام مع زيادة تركيز الوقود الحيوي في الخليط وهذا يرجع الي وجود الاكسجين في المكون.