EXPERIMENTAL INVESTIGATION OF BIO-DIESEL FROM PAPAYA SEED OIL AS A FUEL IN DIESEL ENGINE

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Abstract

The continuous use of petroleum sourced fuels is now widely recognized as unsustainable because of depleting supplies and the contribution of these fuels to the accumulation of carbon dioxide and carbon monoxide in the environment. The papaya seed oil is used to extract the bio-diesel. The extracted bio diesel is blended with sole fuel and B25% blend has been selected. The reason is that with B25% blend the engine can run without any modification in the operational parameters such as injection timing and injection parameters. In order to enhance the performance of the engine with bio-diesel. The blends tested in this study are B25%, B50%, B75% and B100%.

The investigation was carried out in the single cylinder water cooled diesel engine with the sole fuel blended with papaya seed oil and the engine performance and emission characteristics will be analyzed. From the experimental investigation it is observed that the brake thermal efficiency increased for B25% blend by 3.31% when compared to that of sole fuel. The CO, HC, Smoke are found to decrease with the B25% blend with increase in NO_x emission.

Keywords — Bio diesel, Papaya seed oil, Thermal efficiency, Diesel engine.

I. INTRODUCTION

Biodiesel is an alternative fuel for diesel engines that is produced by chemically reacting a vegetable oil or animal fat with an alcohol such as methanol. The reaction requires a catalyst, usually a strong base, such as sodium or potassium hydroxide, and produces new chemical compounds called methyl esters. It is this esters that have come to be known as biodiesel.

Because its primary feedstock is a vegetable oil or animal fat, bio diesel is generally considered to be renewable. Since the carbon in the oil or fat originated mostly from carbon dioxide in the air, biodiesel is considered to contribute much less to global warming than fossil fuels. Diesel engines operated on biodiesel have lower emissions of carbon monoxide, unburned hydrocarbons, particulate matter, and air toxics than when operated on petroleum-based diesel fuel.

The objective of this work is to describe the processing and production of biodiesel by transesterification and pyrolysis process.

A. History of Biodiesel

The diesel engine came into its existence in the year 1893 when the paper titled “The theory and construction of a rational heat engine” was published by a great German inventor Dr. Rudolph Diesel. The use of vegetable oil was first started by Rudolph Diesel. He developed the first diesel engine working on peanut oil at the World’s Exhibition in Paris, 1900. The main focal points for biodiesel production to expand were the oil seed crops. Until 1920s vegetable oils were utilized as the source of energy in the diesel engine. The factors like profitability, availability, low sulfur content, low aromatic content, biodegradability and renewability makes vegetable oils more advantageous over diesel fuel. At present higher market values for challenging uses restricted the utilization of crops for biodiesel production.

B. BACK GROUND

At current production levels, biodiesel requires a subsidy to compete directly with petroleum-based fuels. However, federal and state governments are providing incentives that encourage the rapid growth of the biodiesel industry. Current production levels are 20-25 million gallons/year, but achieving current European levels of 500 million to 1 billion gallons/year should be feasible.

The combined vegetable oil and animal fat production in the United States totals about 35.3 billion pounds per year. This production could provide 4.6 billion gallons of biodiesel. However, the annual consumption of on-highway diesel fuel in the United States is about 33 billion gallons. If all of the vegetable oil and animal fat produced in the U.S. were available to produce biodiesel, it would only displace about 14% of the current demand for on-highway diesel fuel.

II. LITERATURE REVIEW

Knothe (2005) have investigated how ethyl esters were proposed as diesel fuel substitutes as early as 1937 in the Belgian Congo. Widespread investigation of these esters did not occur until the late 1970s and early 1980s when high petroleum prices inspired extensive research into alternative fuels. Vegetable oils were proposed as diesel fuels but were found to be problematic due mostly to their greater viscosity. Problems were found with piston and injector deposits and crankcase oil dilution and resultant oil thickening. Conversion of the oils to their alkyl esters reduced the viscosity to near diesel fuel levels and produced a fuel with properties that were similar to petroleum based diesel fuel and which could be used in existing engines without modifications.

Freedman et al (1999) have experimentally evaluated the results of a parametric study of the transesterification reaction variables that included temperature, molar ratio of alcohol to oil, type of catalyst, and the degree of refinement of the oil. They observed that the reaction proceeded to completion in 1 hour at 60°C but took 4 hour at 32°C. From this it is observed how the degree of reaction depends on the alcohol-to-oil ratio. Significant amounts of partially reacted mono and diglycerides will be present when the alcohol-to oil ratio is too low. From the experimental investigation it was examined an alcohol-to-oil ratio of 6:1 is necessary for a complete single-step reaction. Mono and diglycerides of saturated fatty acids crystallize easily from the biodiesel fuel and can cause fuel filter plugging and other performance problem.

Jon Van Gerpen (2005) have described biodiesel is an alternative diesel fuel produced from vegetable oils and animal fats. It consists of the monoalkyl esters formed by a catalysed reaction of the triglycerides in the oil or fat with a simple monohydric alcohol. But process complexity originates from contaminants in the feedstock, such as water and free fatty acids, or impurities in the final product, such as methanol, free glycerol, and soap. Processes have been developed to produce biodiesel from high free fatty acid feedstock, such as recycled restaurant grease, animal fats, and soap stock.

Y. Zhang (2003) has studied different continuous processes for biodiesel production from virgin vegetable oil or waste cooking oil under alkaline or acidic conditions. Detailed operating conditions and equipment designs for each process were obtained. A technological assessment of these processes was carried out to evaluate their technical benefits and limitations. Analysis showed that the alkali-catalysed process using virgin vegetable oil as the raw material required the fewest and smallest process equipment units but at a higher raw material cost than the other processes.

Weiliang Cao (2005) has showed transesterification of soybean oil in supercritical methanol has been carried out in the absence of catalyst. A co-solvent was added to the reaction mixture in order to decrease the operating temperature, pressure and molar ratio of alcohol to vegetable oil. With propane as co solvent in the reaction system, there was a significant decrease in the severity of the conditions required for supercritical reaction, which makes the production of biodiesel using supercritical methanol viable as an industrial process. A high yield of methyl esters (biodiesel) was observed and the production process is environmentally friendly. Furthermore the co-solvent can be reused after suitable pre-treatment.

R. U. Owolabi and **N. A. Osiyemi (2013)** has described extensive efforts were made in this study to extract oil from Carica papaya seeds (an untapped resource), trans-esterify the extracted oil and check for the fuel properties of the produced papaya seed oil based biodiesel. Normal hexane was used as solvent for the extraction. 63.05g of oil was extracted from 275g of pawpaw seeds to give oil yield of 22.93%. Lyed methanol in 60% excess was reacted with the heated oil with thorough agitation for some minutes. This paper however intends to draw the attention of researchers and policy makers through thorough experimentation on a forgotten resource (papaya seed oil) and its suitability as a major feedstock for biodiesel production so as to conserve the fossil fuel and further create a balance between food security and energy security.

Afolabi et al (2011) explains papaya seed is a waste product of Carica papaya Linn. fruits that is highly abundant in Nigeria. This present study deals with the effect of some potential food processing methods (drying at 45-50oC for 48.0 hours, and fermentation for 72.0 hours) on the seeds. Products from both processing methods, and the unripe seeds were examined for their biochemical properties compared to fresh samples.

Celina Therese S.P (2011), Fatty acid methyl esters (FAME) from Carica papaya L. (papaya) oil were investigated as a potential biodiesel fuel. Oil was extracted from papaya seeds by mechanical pressing, solvent extraction with hexane and solvent extraction with steam. The papaya seed oil contained 10.3% free fatty acid. Thus, a two-step conversion process of acid esterification followed by a conventional alkali-catalyzed transesterification was conducted. Upon testing, papaya FAME was found to have a density of 885 kg m-3 at around 15 ºC, kinematic viscosity of 4.7 mm2 s-1, an acid value of 0.26 mg KOH g-1, a cloud point of 20 ºC, a flash point of 170 ºC, a sulfur content of 0.029%, a sulfated ash content of 0.01%, a free glycerol content of 0.00%, a total glycerol content of 0.16% and a predicted iodine value of 76.0 g I2 (100 g)-1. The FAME complied with three key biodiesel standards [Philippine National Standard (PNS 2020:2003), American Society for Testing and Materials (ASTM D6751-08) and European Standards (EN14214)], except for the kinematic viscosity, which exceeded the limit provided by PNS.

C. S. Wong et al (1998) Biodiesel production from vegetable oil has gained attention as an alternative fuel to minimize the usage of fossil fuels and reduce greenhouse gases pollution. In Malaysia, oils from local fruit seeds of papaya and rambutan are potential feedstock for biodiesel production due to their high lipid contents and easily available. In the present study, papaya and rambutan seed oils were extracted via soxhlet apparatus using n-hexane and the oil yields were in between 34–40%. The extracted oils were subjected to enzymatic transesterification by the immobilized Candida rugosa lipase as a catalyst under room temperature with varies molar ratios of methanol to oil. The highest biodiesel yield for papaya seed oil and rambutan seed oil was found to be 96% and 89% at methanol-to-oil ratios of 6:1 and 8:1, respectively.
Based upon the literature survey no one done papaya seed as biodiesel. Hence in this work we focus seed biodiesel.

III. BIODIESEL PRODUCTION

A. TRANSESTERIFICATION PROCESS

Transesterification is also called alcoholysis, is the displacement of alcohol from on ester by another alcohol in a process similar to hydrolysis.

This process has been widely used to reduce the viscosity of triglycerides. The transesterification reaction is represented by the general equation

$$\text{R COOR' + R''} \rightarrow \text{R COOR'' + R' OH}$$

If methanol is used in the above reaction, it is formed as methanolysis. The reaction of glyceride with methanol is represent by the general equation triglycerides are readily transesterified in the presence of alkaline catalyst at atmospheric pressure and at a temperature of approximately go to 70°C with an excess of methanol.

The mixture at end of the reaction is allowed to settle. The lower glycerol layer is drawn off while the upper methyl ester layer is washed to remove entrained glycerol and is then processed further.

The excess methanol is recovered by distillation and sent to rectifying column for purification and recycled. The transesterification works well when the starting oil is of light quantity. However, quite often low quality oils are used as raw materials for biodiesel preparation. In case where the free fatty acid content of the oil is above 4%, difficulty arise due to formation of soaps which promote emulsification during the water working stage and at an FFA content above 2% he process becomes unworkable.

If the free fatty acid content of the oil is below 4% single stage process is adopted. If the free fatty acid content s greater than 4% double stage process is adopted.

The most important variable that influence transesterification reaction time and conversion are;

- Oil temperature
- Reaction temperature
- Ratio of alcohol to oil
- Intensity of mixing
- Purity of reactants

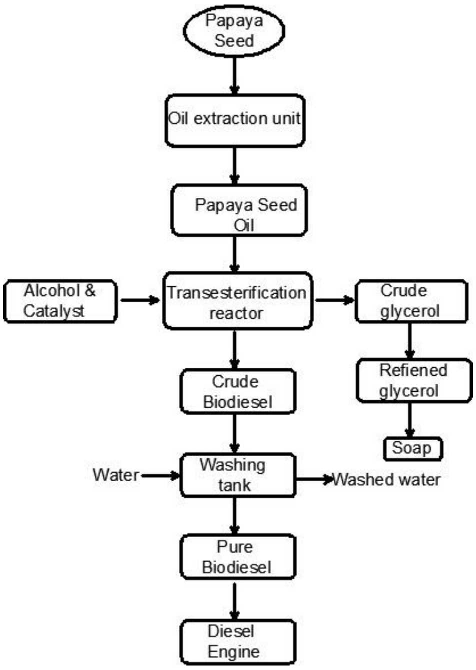
B. Papaya Seed

Mature papaya fruits (*Carica papaya* L. variety Batek Batu) were purchased from a local market in Chennai. Fruits that were orange greenish in color and free from any defect and injury were selected. The fruits were cut into two longitudinal halves and the seeds removed manually. The seeds were dried in an oven at 60°C for 24 hour (Marfo *et al.*1986) and then kept in a sealed bottle under cool dry storage. The seeds were ground into fine powder with a Waring blender before use.

Figure 1 Papaya fruit with seeds

Table 1 Properties of diesel, papaya raw oil and papaya biodiesel

Properties	**Diesel**	**Papaya Raw oil**	**Papaya B100%**
Specific gravity	0.835	0.9211	0.8811
Kinematic viscosity @ 40c in CSt	3.0	36.47	4.52
Flash point	44°C	295°C	159°C
Fire point	49°C	308°C	171°C
Calorific value	44660	41371	42460



C. Objective and Methodology

The objective of the present work is to identify suitable non edible oil to extract biodiesel and to modify the piston to enhance the performance of the engine.

- Selecting the suitable non edible oil to prepare the biodiesel.
- Based upon the literature survey papaya seed oil has been chosen as source to extract the biodiesel.
- The physical properties of the papaya seed oil biodiesel and its diesel blends is shown.
- To reduce the viscosity of the papaya seed oil, double stage transesterification process is carried out.
- The biodiesel extracted from papaya seed oil is blended with diesel and experimental investigation is carried out on diesel engine.
- In order to achieve enhanced engine performance and emissions were implemented in DI diesel engine.

Methodology

- In this project work papaya seed oil is used as a biodiesel.
- The experiment has been carried out in Kirloskar, single cylinder, four stroke, water cooled diesel engine with all necessary equipment to study the engine performance and emission characteristics.
- The experimental investigation of the engine characteristics is carried out with four blends namely B25% , B50%, B75% and B100% .
- The reason for choosing B25% (Biodiesel 25% + diesel 75%) blend is that it shows better results when compare to other blends and it can be operated without any engine modification.

IV. EXPERIMENTAL SETUP AND PROCEDURE

A. EXPERIMENTAL SETUP

This project work has been carried out using different blends of furnace oil as fuel on a single cylinder, water cooled, 4-stroke, diesel engine.

Details of the engine specification are given in table. Fuel flow rate is obtained on the gravimetric basis and the air flow rate is obtained on the volumetric basis. The engine was coupled to an eddy current dynamometer for load measurement and the smoke density was measured using an AVL smoke meter. NO_x emission is measure with help of an exhaust gas analyzer. AVL Di gas analyzer is used to measure the rest of the pollutants. AVL combustion analyzer is used measure the combustion characteristic of the engine. A burette is used to measure the fuel consumption for a specified time interval. During this interval of time, how much fuel the engine consumes is measured, with the help of the stopwatch. The experimental set up is indicated in figure.

Table 2 Specification of the Test Engine

Type	Vertical, water cooled, Four stroke
Number of cylinder	1
Bore Diameter	87.5 mm
Compression ratio	17.5:1
Maximum power	5.2 kW
Speed	1500 rpm
Dynamometer	Eddy current
Injecting timing	23° before TDC
Injection pressure	220 kgf/cm^2

Table 3. Specifications of AVL Di Gas Analyzer

Make	AVL
Type	AVL Di Gas 444
Power Supply	11...22 volage ≈ 25 W
Warm up time	≈ 7 min
Connector gas in	≈ 180 I/h, max.over pressure 450 hPa
Response time	$T_{95} \leq 15s$
Operating temperature	5...45 °C
Storage temperature	0...50 °C
Relative humidity	≤ 95%, non-condensing
Inclination	0...90°∠
Dimension (w x d x h)	270 x 320 x 85 mm^3
Weight	4.5 kg net weight without accessories
Interfaces	RS 232 C, Pick up, oil temperature probe

Table 4. Specifications of AVL Smoke

Make	AVL 437 Smoke meter
Type	IP 52
Accuracy and reproducibility	± 1 % full scale reading
Measuring range	0 to 100 opacity in % 0 to 99.99 absorption m^{-1}
Measurement chamber	Effective length 0.430 m ± 0.005m
Heating time	220 V approximately 20 min.
Light source	Halogen bulb 12 V/5W
Maximum smoke temperature	250 °C
Power supply	190 – 240 V AC, 50 Hz, 2.5 A
Dimensions	570mm × 500mm × 1250mm

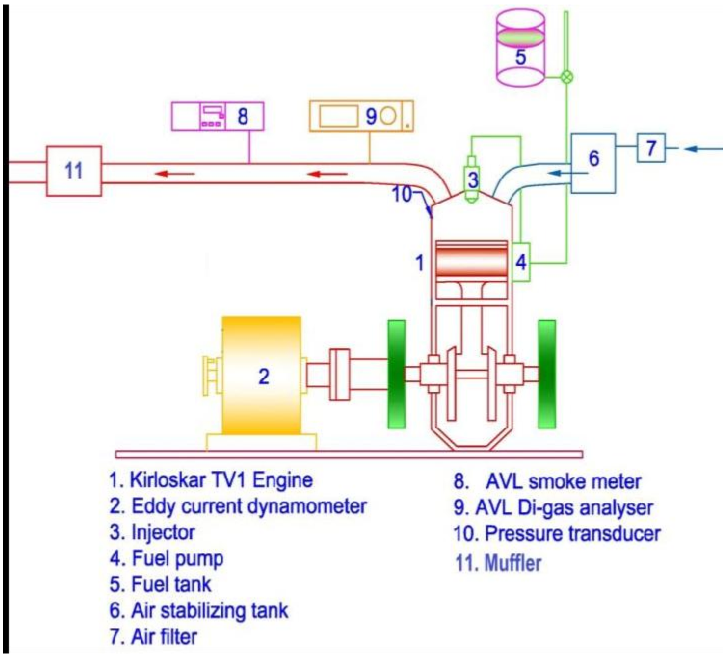


Figure 2. Experimental setup for test engine (Kirloskar TV-1 Engine)

Figure 3. Photograph view AVL Di-gas Analyzer

Figure 4. Photographic view of AVL smoke meter

B. EXPERIMENTAL PROCEDURE

The engine was allowed to run with neat diesel at a various loads for nearly 10 minutes to attain the steady state constant speed conditions. Then the following observations were made.
The water flow is started and maintained constant throughout the experiment. The load, speed and temperature indicators were switched ON. The engine was started by cranking after ensuring that there is no load. The engine is allowed to run at the rated speed of 1500 rpm rev/min for a period of 20 minutes to reach the steady state.
The fuel consumption is measured by a stop watch. Smoke readings were measured using the AVL smoke meter at the exhaust outlet. The amount of NOx was measured using AVL Di gas analyzer exhaust outlet. The exhaust temperature was measured at the indicator by using a sensor. Then the load is applied by adjusting the knob, which is connected to the Eddy Current Dynamometer. Experiments were conducted using neat diesel fuel and a different blend of papaya seed oil the above said procedure is adopted.

V. RESULT AND DISCUSSIONS

The results of the experimental investigation carried out have been furnished hereunder.

A) Brake Thermal Efficiency

Figure 8.1 shows the variations of brake thermal efficiency with brake power for various blends of bio-diesel. The blend B25% shows increase in Brake thermal efficiency when compared to that of diesel fuel and all other blend.. It shows an increase of 3.31% when compared to that of diesel fuel at full load. The reason is that the higher oxygen content provided by B255% of biodiesel enhances complete combustion and reduces the viscosity of the blend thereby improved atomization of the blend is achieved. The papaya oil also contains higher oxygen content enhances complete combustion.

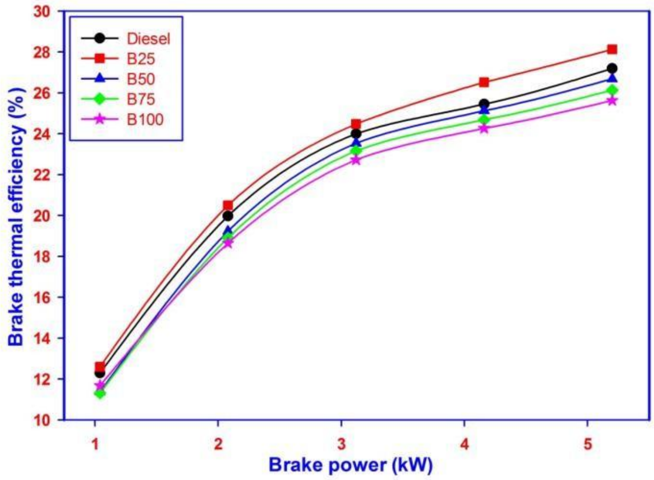


Fig. 5. Brake thermal efficiency against Brake power

B) Specific fuel consumption

Figure 8.2 shows the variations of specific fuel consumption with brake power for various blends of biodiesel. As brake power increases, SFC decreases. The blend B25% shows lesser fuel consumption when compared to that of diesel and all blends and the probable reason is higher heating value of the blends.

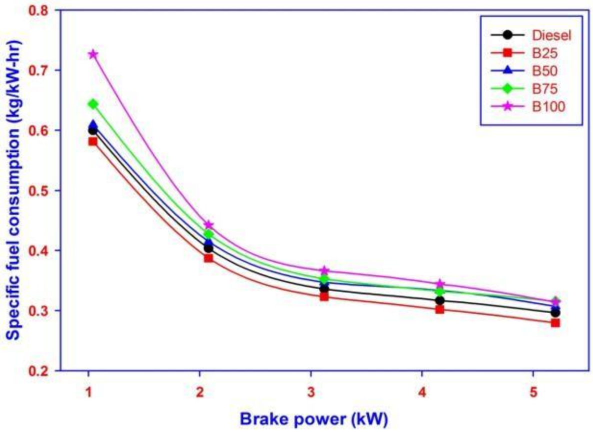


Fig. 6. Brake thermal efficiency against SFC

C) Smoke density

Figure 8.3 shows the variations of smoke density with brake power for various blends of bio-diesel. The blend B25% shows decreases in smoke density when compared to that of other blends. It has shown a decrease of 12.67% when compared to that of diesel fuel at full load. The reason is that the blend B25% exhibit complete combustion with higher oxygen content in the blend.

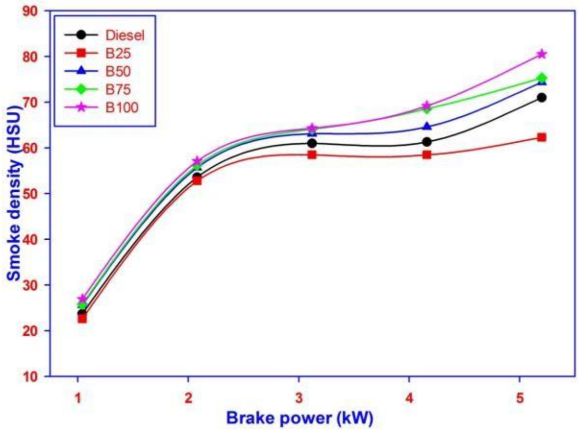


Fig. 7. Smoke density against Brake power

VI. CONCLUSION

The physical properties of the biodiesel produced from papaya seed oil through trans-esterification is measured and compared to that of diesel fuel.
Using of bio-diesel and its blend in varying proportions as a fuel in diesel engine causes improvement in engine performance and engine efficiency.
The blends used in this study are B25%, B50%, B75% and B100%. In order to enhance the engine performance and emission, B25% blends shows significant reduction in CO, HC and smoke emission when compared to that of diesel fuel. The blend B25% exhibit better performance, emissions characteristics. The NOx emission for bio-diesel blend is significantly raised. In future in order to reduce the NO_x emission, EGR may be employed to attain the desired result.

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