Extraction Of Simarouba Biodiesel And Experimental Investigation Of Its Suitability As Fuel For CI Engine

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Abstract— The availability of fossil fuels are depleting at faster rate. So the emissions from the fossil fuels also increasing day by day leading to high environmental pollution. So an alternative fuel is necessary and a need of the automobile sector, Bio-diesel is one of the most promising alternatives for diesel needs. Use of edible oils may create shortage of oil for daily food. This required identification of new kinds of non-edible vegetable oil. With this objective, the present work has focused on the extraction of bio-diesel, from the simarouba seeds and testing the performance, combustion and emission characteristics of diesel engine using simarouba oil and its blends with diesel. In this investigation, the blends of varying proportions of simarouba biodiesel with diesel should be prepared, analyzed, and compared the performance and exhaust emission with diesel using, Single cylinder, 4stroke diesel engine.

We also want to study the fuel properties like viscosity, calorific value, cetane number. The performance and emission characteristics of blends are evaluated at variable loads and constant rated speed and will try to find the performance of blends of simarouba oil and get a result, we will check out up to what extent we can replace the conventional diesel with the bio-diesel, and also to find the percentage emissions of CO, CO2, HC, smoke & NOX of this blend is less than the conventional diesel.

Keywords— IC engine, CI engine, SI engine, alternate fuels, cetane number, octane number

I INTRODUCTION

India is importing crude petroleum & petroleum products from Gulf countries. Indian scientists searched for an alternate to diesel fuel to preserve global environment and to withstand economical crisis. So, vegetable oils from plants both edible, crude non-edible and Methyl esters (Bio-diesels) are used as alternate source for Diesel oil. Bio-diesel was found as the best alternate fuel, technically and environmentally acceptable, economically competitive and easily available.

Several types of oils that are extensively studied include Sunflower, Soya bean, Peanut, Rapeseed Rice brawn and karanji etc. one of the disadvantages in using these oils in diesel engines is nozzle deposits, which drastically affects. The engine performance and emissions. The refining process of the refining oil gives better performance compared to crude vegetable oil.

Goeringetal studied the properties for eleven types of vegetable oils to determine the best suitable oil which is used as alternative to diesel. Among the eleven types of oils tested, corn, rapeseed, sesame, cottonseed, and soya bean oils have most favorable fuel properties.

There is an improvement in the engine performance when this modified vegetable oils are used instead of base vegetable oils. This improvement in performance can be attributed to good atomization of these modified fuels in
the injector nozzle and a significant reduction in viscosities.

The performance of non-edible types like rice bran and cotton seed oils was found satisfactory.

The idea of using vegetable oil as fuel for diesel engines is not a new one. Rudolph Diesel used peanut oil as fuel in his engine at Paris Exposition of 1900. Inspite the technical feasibility, vegetable oil as fuel could not get acceptance, as it was more expensive than petroleum fuels. Later various factors as stated earlier renewed the interests of researchers in using vegetable oils as substitute for diesel engines. The densities are viscosity of the blends increase with the increase of Bio-diesel concentration in the fuel blend. It also reduces the filter clogging and ensures smooth flow of oil. Some of the researchers conducted experiments on diesel engine using non-edible vegetable oils as alternative fuels and found maximum Break thermal efficiency. BSFC. Emissions like CO, HC also increased without any engine modification. The use of biodiesel in conventional diesel engine results un substantial reduction in the emission of unburned hydrocarbons, carbon monoxide and particulate.

THE USE OF VEGITABLE OIL AS AN ALTERNATIVE TO CONVENTIONAL DIESEL FUEL:

There has been a consensus among many researchers for several years that vegetable oils could serve as an alternative to conventional fuels in diesel engines. Many articles have been published showing that vegetable oil could be used to fuel a diesel-powered engine under normal conditions. For example, one researcher ran a tractor on sunflower seed oil for 1000 hours with an 8% power loss, and another researcher demonstrated that rapeseed oil had similar energy output to diesel. However, further researcher documented that there are problems associated with the use of vegetable oil such as heavy wax and gum deposits in diesel engines and carbon build up in the combustion chamber with sunflower oil. Plus, engines run on rapeseed oil reportedly had some difficulties on account of carbon deposits on piston rings, valves and injectors after 100 hours.

A more promising study in the support of using vegetable oil evaluated several chemical and physical properties of a variety of oils and found that the carbon deposits were reduced when the oil was heated prior to combustion, and that the carbon deposits were a function of oil composition such as high viscosity. Research has demonstrated that blending vegetable oil with conventional diesel fuel at different proportions can minimize deposits and extend the life of the engine. Researchers typically blended diesel with variety of oils like peanut, cottonseed, sunflower, rapeseed, and palm oil and the mixing ratio could reach to 50:50.

They observed that one could run the engines on the blend of vegetable oils/diesel with no immediate adverse effects and long term lifecycle effects that were similar to those found on engines that have been operated with pure diesel. However, the percent of vegetable oil in the blends was a large variable in many of the studies; blends with higher ratio of vegetable oil to diesel caused increased carbon deposits. The studies on blending vegetable oil with conventional diesel fuel also suggested that the increase in carbon deposits could be a result of the different atomization and injection characteristics that are likely because of high viscosity and low volatility of the vegetable oils.

THE DEVELOPMENT OF BIODESEL FROM VEGETABLE OIL:

Vegetable oil has potential to be considered as an alternative diesel fuel, but it has short comings like high viscosity, low volatility, poor cold flow properties, and the carbon buildup in engines [45, 46]. The drawbacks have
directed the investigation to search for various derivatives of the fuel of which biodiesel seem to be the most popular one. The term biodiesel was introduced to the U.S. mainstream in 1992 by the National Soy Diesel Development Board presently known as the National Biodiesel Board, which has been a pioneer in commercialization of biodiesel in the United States.

The chemical definition of biodiesel is the mono alkyl esters of long chain fatty acid that comes from a renewable resource or lipid. Lipids or oils are water insoluble, hydrophobic substances that consist of one mole of glycerol and three moles of fatty acid, and are usually referred to as triglycerides. The composition of oils consists of 90-98% triglycerides. Oils and fats derived or collected from different sources have diverse fatty acid compositions. Fatty acid compositions differ in their carbon chain length and in the number of bonds they contain. The most common fatty acids in vegetable oil are stearic, palmitic, oleic, linoleic and linolenic. Some common saturated fatty acids are stearic, palmitic, dihydroxystearic, and some common unsaturated fats are oleic, linoleic, ricinoleic, palmitoleic, and linolenic.

**TRANSESTERIFICATION:**

![Chemical equation diagram]

**The Fatty acid composition of Simarouba oil determined by Gas Chromatography in which the total number of Carbon and number of double bond is mentioned by first and second subscripts**

**SIMAROUBA GLAUCA:**

Simarouba glauca is grown widely across South America, Central America, and India. The most economically important part of the plant is the seed oil. The Simarouba seed contain between 55-65% oil content. The oil has many industrial uses, including its ability to be turned into fat or margarine. The fruits have a semi-sweet pulp that is suitable for eating or use in the beverage industry. The leaf litter and seed cake are good sources of manure. Lastly, the bark and leaves have been known to have medicinal qualities and have at least one patent has been applied for using Simarouba glauca. It is popular because all the parts of the tree can be used in different processes.

Simarouba glauca’s seed and tree

**METHODS:**

**SEED DECORTICATION:**
Decortication is the act of separating the seed husk or seed shell from the actual seed of kernel. Decortication is an essential step prior to milling and extracting the oil from the kernel or seeds. While there is extensive research on the decortication of various edible feedstock there is still little research done on the decortication of alternative feedstock like Jatropha curcas and Simarouba glauca.

The decorticator used for the experiment was a mechanical model used for the decortication of ground nut that was adapted to process other varieties of seeds. During the time of the experiment the seed decorticator was being used process seeds of neem, Jatropha curcas, and Simarouba glauca.

For this research 200kg of the whole seeds of Simarouba glauca were input into the decorticator in 10kg increments; the time it took to decorticate each increment was recorded along with the weight of seeds being separated and the shells. The seeds that failed to separate were weighed with the shells. The average recovery of seed kernels compared to shells or husk for each increment was calculated to determine the efficiency of the process.

\[
Dc = \left[ \frac{(Ws + Wb + Wh)}{Wt} \right] \times 100
\]

Where, \(Dc\) = Decortications efficiency;

\(Wt\) = Weight of sample,

\(Wh\) = Weight of husk,

\(Wb\) = Weight of broken,

\(Ws\) = Weight of decorticated sample

OIL EXPPELLING AND EXTRACTION:

Expelling refers to the process of pressing the liquid out of liquid containing solids mechanically where extraction refers to the process of separating a liquid-solid system. Mechanical expression of seed oils using a screw press is said to be the oldest and most popular method of expelling oil from seeds in the world. While solvent extraction has proved to be more efficient the simplicity and safety aspects of expelling have made it the more advantageous process. Plus, solvent extraction adds chemicals contaminating the protein rich cake that can be used or sold to increase the efficiency of the production model.

Oil Expeller

OIL TRANSESTERIFICATION:

The seed oil that was extracted in the above process was then converted into biodiesel using simple transesterification. In the process of transesterification the triglycerides from the Simarouba glauca oil are converted into fatty acid methyl ester using a short 27 chain alcohol (methanol) and alkaline catalyst (Sodium Hydroxide). In most biodiesel production models methanol or ethanol is used as the alcohol and sodium hydroxide or potassium hydroxide as alkaline catalyst to produce biodiesel. The process was carried out in 1L batches at atmospheric pressure in a closed vessel at a constant temperature of 60 °C. Once, the oil reached a constant temperature in the vessel a mixture of methanol and sodium hydroxide was added. The amount of sodium hydroxide was determined using the acid value and the following equation:

\[
\text{Amount catalyst} = 3.5g \text{ sodium hydroxide} + A
\]
Where “A” is the acid number of the oil. The oil, methanol, and sodium hydroxide were mixed continuously for 1-1.25 h.

The reactor set up used for transesterification

The liquid from the vessel is placed in a separating funnel where the denser glycerin sinks down the bottom where it is easily separated. Following, separation the biodiesel was washed once with 1000ml of hot water acidified with organic acids, and then several washes of just hot water. Finally, the biodiesel was heated to a temperature of 120°C to remove the moisture from the mixture.

Identification of Simarouba glauca oil and biodiesel fuel properties testing procedures for the identification of the fuel properties of Simarouba glauca oil and biodiesel were adapted from Biochemical methods. The testing procedures are comparable but not fully up to date with the testing procedures required for certification under ASTM standards, Indian standards, or European standards. Fuel properties 28 tested for include acid value, viscosity, iodine value, density, calorific value, flash point, pour point, and ash contents.

**PERFORMANCE OF BIODIESEL BLENDS WITH CONVENTIONAL DIESEL IN A 4-STROKE SINGLE CYLINDER VERTICAL TYPE DIESEL TEST ENGINE:**

Fuel properties tested for Simarouba glauca oil and its biodiesel compared to ASTM standards, European standards, and other biodiesels:

<table>
<thead>
<tr>
<th>Property</th>
<th>S. glauca Oil</th>
<th>S. glauca Oil (20%) Blend</th>
<th>ASTM D 976</th>
<th>EN 14214</th>
</tr>
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<tbody>
<tr>
<td>Acid Value</td>
<td>2.2660</td>
<td>2.2465</td>
<td>&lt;0.5</td>
<td>&lt;0.30</td>
</tr>
<tr>
<td>Viscosity (cst)</td>
<td>60.99</td>
<td>60.33</td>
<td>60.0</td>
<td>60.0</td>
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<tr>
<td>Calorific Value</td>
<td>32.14</td>
<td>19.229</td>
<td>9.8</td>
<td>9.8</td>
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<tr>
<td>Density</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>Cold Flow</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
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<tr>
<td>Pour Point</td>
<td>47</td>
<td>47</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Flash Point</td>
<td>26.30</td>
<td>26.28</td>
<td>26.30</td>
<td>26.30</td>
</tr>
<tr>
<td>Ash Contents</td>
<td>0.010</td>
<td>0.012</td>
<td>0.010</td>
<td>0.010</td>
</tr>
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</table>

**RESULTS:**

**BRAKE THERMAL EFFINCE:** It is defined as the ratio of the heat equivalent of the brake output to the heat supplied to the engine. For all the cases, with the increase of engine load, the thermal efficiency increases. The BTE of the Simarouba blends was lower than that of diesel for the entire range of operation. The BTE of 20% blend of simarauba oil compared with diesel exhibits the highest value at 26.75% of total load obtained at 4.06 kw against 26.88% of diesel. The drop in thermal efficiency is attributed to the poor combustion characteristics of the vegetable oils due to their high viscosity and poor volatility.
**BRAKE SPECIFIC FUEL CONSUMPTION:** It is a measure of the **fuel efficiency** of any prime mover that burns fuel and produces rotational, or shaft, power. It is typically used for comparing the efficiency of internal combustion engines with a shaft output. The variation of brake specific fuel consumption with brake power output for simarauba oil and its blends with diesel in the test engine are shown in the figure 4. Diesel has lower bsfc compared to all other blends; however 20% blend of simarauba oil has lower SFC values. The increase in bsfc of Simarauba oil and their blends may be due to their lower calorific value. For the fuels tested, brake specific fuel consumption decreased with increase in load. One possible explanation for this reduction could be due to higher percentage of increase in brake power with load.

**BRAKE SPECIFIC ENERGY CONSUMPTION:**

Brake specific energy consumption is the ratio of energy obtained by burning fuel for an hour to the actual energy or Brake power obtained at the wheels. It is dimensionless. It is indicative how effectively the energy obtained from the fuel is reaching the wheels. The brake specific fuel consumption is not a very reliable parameter to compare the two fuels as the calorific value and density of the blend follow a slightly different trend. Hence, brake specific energy consumption is a more reliable parameter for comparison. Figure 5 shows the comparison of brake specific energy consumption with brake power for diesel, simarouba and its blends. Brake specific energy consumption of methyl ester of simarouba oil for entire range of operation is comparable to that of diesel. At rated load brake specific energy consumption of methyl ester of simarouba oil is found 40% lower than that of diesel. Energy based fuel economy of engine is better than that of diesel.

**EXHAUST GAS TEMPERATURE:** The EGT of all blends and diesel increase with increase of operating loads. This is an indication of lower exhaust loss and could be possible reason for higher performance.

**EMISSION CHARACTERISTICS:**

**CARBON MONOXIDE:** CO emission depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. It is observed that the CO emission initially decreases at lower loads sharply increases after 4 kW of power for all test fuels. And the diesel and simarouba oil with 80% blend has more emission of CO compared with blends of simarouba oil like S20, S40, S60 and S100. This due to incomplete combustion at higher loads which results in higher CO emissions. It is also seen that the CO Emission decreases with increase in percentage of additive in the blends. From this graph it is revealed that S100 (pure simarouba oil) shows lowest carbon monoxide emission compare to all other test fuels up to 4kw of power and then increases due to incomplete combustion.
UNBURNTED HYDROCARBAN: The emission of HC is decreasing with increase of loads. It can be confirmed that both conventional diesel and biodiesel had the same functional group of C–H. However, the conventional diesel had no oxygen group, whereas biodiesel showed oxygen functional group. Therefore, the biodiesel with the existence of oxygen could be promoted cleaner and complete combustion. On the other hand, the conventional diesel without any oxygen produced more black smoke and incomplete combustion during burning.

SMOKE: The biodiesel blend produced less black smoke compared to the conventional diesel due to the oxygen content. Moreover, the incomplete combustion of hydrocarbon will produce black smoke too. Thus, the conventional diesel is an incomplete combustion but when it is mixed with biodiesel, the combustion produced is more complete. A complete combustion was obtained with higher biodiesel blend. Hence, the biodiesel blend is much more environmentally friendly compared to the conventional diesel.

OXIDES OF NITROGEN: NOx emission is primarily a function of total oxygen inside the combustion chamber, temperature, pressure, compressibility, and velocity of sound. Invariably biodiesel has S level of oxygen bound to its chemical structures. Thus, oxygen concentration in biodiesel blends fuel might have caused the formation of NOx. Furthermore, the increase of NOx emission is due to the higher cetane number of biodiesel which will reduce the ignition delay. The increase of NOx emission is a result of the reduced ignition delay. However, the NOx emissions can be reduced through engine tuning or using exhaust catalytic converter. At any rate, the NOx still can be reduced with the advanced technologies such as catalytic converter, EGR and engine tuning.

CYLINDER PRESSURE: The fraction of fuel burnt during the premixed burning phase decides the cylinder pressure. Vegetable oils have higher cetane number. This shortens the ignition delay period. This results in reduction in fuel injection, maximum pressure and temperature when compared with those of diesel.

The trend is of S100 is however is same as that of D100 pressure diagram. The cylinder peak pressure is found highest with D100 followed by S100.

From the observation it was noted that the occurrence of pressure moves away for S100 compared to D100. This shows that S100 has longer ignition delay compared to D100. This is because of low cetane number of S100. Due to poor volatility, high viscosity, lower heating value and poor spray characteristics of S100 leads to less fuel being prepared for rapid combustion.

NET HEAT RELEASE RATE: S100 shows lower heat release rate compared to D100 during premixed burning phase. The poor atomization and poor fuel-air mixing is attributed to high viscosity and poor volatility of vegetable oils. This consequently leads to higher exhaust gas temperature and loss of power because burning occurs in diffusion phase.

OIL TRANSESTERIFICATION: From the 9.223kg mechanically expelled oil, 9L of oil was separated leaving about 100ml of simarouba oil as excess from the whole process. The oil was converted into biodiesel in nine 1L batches and 8.122L of biodiesel was produced. The average yield percentage of transesterification was (8.122/9.223) x100= 90.24%. There was 2.712L of un-reacted material, which was mostly glycerin (another value added product) separated from the oil.

COMBUSTION CHARACTERISTICS:
FUEL PROPERTIES:

All fuel properties were determined in triplicate and the result shown is the average of the three trials. Table 4 shows List of fuel properties obtained for Simaroubaglauca biodiesel and oil.

<table>
<thead>
<tr>
<th>PROP</th>
<th>Glauca biodiesel</th>
<th>Glauca Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Value (mg KOH/mg)</td>
<td>0.24905</td>
<td>2.2485</td>
</tr>
<tr>
<td>Viscosity at 40°C (cst)</td>
<td>12.609</td>
<td>60535</td>
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<tr>
<td>Calorification (MJ/kg)</td>
<td>32.143</td>
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<tr>
<td>Saponification</td>
<td>179.561</td>
<td>185.9317</td>
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<tr>
<td>Density</td>
<td>867</td>
<td>Room Temperature</td>
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<tr>
<td>Cloud Point</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Pour Point (Celsius)</td>
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<td>54.28</td>
</tr>
<tr>
<td>Iodine Number</td>
<td>56.03</td>
<td></td>
</tr>
<tr>
<td>Flash Point (Celsius)</td>
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<td></td>
</tr>
<tr>
<td>Ash Content</td>
<td>0.00485</td>
<td></td>
</tr>
</tbody>
</table>

PERFORMANCE IN ENGINE TEST:

In order to calculate the results of the performance test in the diesel engine the calorific content and density of each blend was required. When the Simarouba biodiesel was mixed with the diesel the calorific content increased, the viscosity was reduced, the cloud point dropped, and the density fell as the percent of conventional diesel was increased.
### HANDLING & STORAGE OF BIO-DIESEL

As a general rule blends of bio-diesel and petroleum diesel should be treated like petroleum diesel. Bio-diesel vegetable methyl esters contain no volatile organic compounds that can give rise to poisonous or noxious fumes.

There is no aromatic hydrocarbon (benzene, toluene, xylene) or chlorinated hydrocarbons. There is no lead or sulphur to react and release any harmful or corrosive gases. However, in case of bio-diesel blends significant fumes released by benzene and other aromatics present in the base diesel fuel can continue.

On eye contact bio-diesel may cause eye irritation. Safety glasses or face shields should be used to avoid mist or splash on face and eyes. Fire fighting measures to be followed as per its fire hazard classification. Hot fuel may cause burn. Bio-diesel should be handled with gloves as it may cause soft skin. Mild irritation on skin can occur.

For long term Storage stability of Bio-diesel and blends adequate data are not available. Based on experience so far it is recommended that bio-diesel can be store up to a maximum period of 6 months. Some anti-oxidant additives are also used for longer periods of storage. Similarly periods are applicable for storage of bio-diesel and its blends in vehicle fuel tank. Due to being a mild solvent, bio-diesel has a tendency to dissolve the sediments normally encountered in old tanks used for diesel fuel and cause filter blockage, injector failures in addition to clogging of fuel lines. Brass, copper, zinc etc oxidizes diesel and bio-diesel fuels and create sediments. The fuel and fitting will start changing color as the sediments are formed. Storage tank made of aluminium, steel etc should be used.

**STABILITY OF BIO DIESEL:** Bio-diesel ages more quickly than fossil diesel fuel due to the chemical structure of fatty acid esters present in biodiesel.

There are three types of stability criteria, which need to be studied:

---

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<th>LOAD</th>
<th>SPEED (N) (rpm)</th>
<th>TIME (min</th>
<th>MANOSTATE</th>
<th>h,(m)</th>
<th>h,(m)</th>
<th>h,(m)</th>
<th>h,(m)</th>
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<tr>
<th>VS</th>
<th>DP</th>
<th>Bio</th>
<th>IP</th>
<th>SI</th>
<th>Base</th>
<th>Long.</th>
<th>%</th>
<th>Index</th>
<th>%</th>
<th>Index</th>
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**STABILITY OF BIO DIESEL:** Bio-diesel ages more quickly than fossil diesel fuel due to the chemical structure of fatty acid esters present in biodiesel.
(a) Oxidation stability (b) Thermal Stability and (c) Storage Stability

Poor oxidation and thermal stability can cause fuel thickening, formation of gum and sediments and may also affect engine oil due to dilution. Current knowledge and database is still inadequate. It is desirable to carry out tests on biodiesel from different feedstock available and generate data in relation to fuel composition. Very little data is available on the long-term storage stability of biodiesel.

BIODEGRADABILITY OF BIO DIESEL: Biodiesel is highly biodegradable in freshwater as well as soil environments. 90–98% of biodiesel is mineralized in 21–28 days under aerobic as well as anaerobic conditions. Biodiesel has been reported to remove twice the amount of crude oil from sand as conventional shoreline cleaners.

Biodiesel increases the biodegradability of crude oil by means of co-metabolism. More than 98% degradation of pure biodiesel after 28 days in comparison to 50% and 56% by diesel fuel and gasoline respectively.

Also, the time taken to reach 50% biodegradation reduced from 28 to 22 days in 5% biodiesel mixture and from 28 to 16 days in case of 20% biodiesel mixture at room temperature. The biodegradability of the mixture was reported to increase with addition of biodiesel. And is depicts in the biodegradability of fossil diesel under different conditions.

CONCLUSION:

During our research I determined how efficient the production process of Simarouba glauca biodiesel by converting 100kg of Simarouba glauca seeds into oil and then converting the oil into 13ltrs. of biodiesel. I determined that there are three major processes involved in the biodiesel production system: seed decortication, oil expelling, and transesterification. I was able to estimate the efficiency of each part of the process and recorded data that might help future studies. Furthermore, I determined fuel properties for the Simarouba glauca biodiesel and oil produced using The biofuels laboratories. The fuel properties determined were then compared to popular feedstock and quality standards. Finally, the Simarouba glauca biodiesel was blended with conventional diesel fuel and tested in a diesel test engine to determine its performance characteristics.

The properties of Simarouba and its blends were analyzed. High viscosity and cloud point makes the simarouba not compatible to be used raw in the engine and hence justifies the need for transesterification. The high catalytic activity re-usability lower emission rates, improved engine performance and makes it a promising candidate when compared with conventional catalysts. As can be observed S20 is the most suitable biodiesel blend among all. The first criterion is that the engine power output of S20 is not much different from conventional biodiesel. Secondly, the specific fuel consumption of S20 is much lower than the S40 and S60. In this criterion, S20 is selected, as the SFC is slightly the same with Diesel, and the higher biodiesel blend produces better combustion. Lastly, the S20 has lower average percentage of change in CO2, CO, and HC compared to Diesel. Yet, S20 is producing higher NOx emission. Nevertheless, the S20 is still the suitable biodiesel blend amongst all as the NOx emission can be reduced with the advanced technologies

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