

Characterization of Cotton Seed and Simarouba Oil Blend and Exploration of its Suitability as an Alternate Fuel for CI Engine

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ABSTRACT— *Rapid growth in Transportation, Industrialization and Civilization from time to time is resulting in continuous increasing demand for energy. At the same time the decreasing petroleum resources has led to the search for alternative fuels which is renewable and sustainable. Day by day depletion of liquid fossil fuels makes it very necessary to find out an alternative liquid fuel like biodiesel. In this paper, an attempt is made to blend cotton seed and Simarouba oils in equal quantity, produced from the seeds of cotton seed and Simarouba respectively. Biodiesel resulting out of cotton seed and Simarouba oil blend was further subjected to esterification and trans-esterification process. Production optimization of biodiesel was done using heterogeneous ($MgPO_4$) as catalyst and the various properties of this blend are evaluated to explore its suitability as an alternate fuel. Characterization and subsequent comparison of various properties viz., flash point, cloud and pour point, density and specific gravity, viscosity, ash content and carbon residue, with ASTM prescribed standards suggested that the proposed blend B50-50 is a potential candidate to qualify as an alternate fuel for a CI engine*

Keywords--- Transesterification, Hybrid vegetable oil, cotton seed oil, simarouba oil

1. INTRODUCTION

Petroleum based fuels are fast depleting due to their limited availability coupled with increasing demand. They are also major contributors of air pollutants. Major portion of today's energy demand on India is being met with fossil fuels. Hence alternate fuels for engines should be derived from indigenous sources.

Energy is considered as a critical factor for economic growth, social development and human welfare. Since their exploration, the fossil fuels continued as the major conventional energy source with increasing trend of modernization and industrialization, the world energy demand is also growing at faster rate. To cope up the increasing energy demand, majority of the developing countries import crude oil apart from their indigenous production. This puts extra burden on their home economy. Hence, it is utmost important that the options for substitution of petroleum fuels be explored to control the burden of import bill. There are limited reserves of the fossil fuels and the world has already faced the energy crisis of seventies concerning uncertainties in their supply. Fossil fuels are currently the dominant global source of CO₂ emissions and their combustion is stronger threat to clean environment. Increasing industrialization, growing energy demand, limited reserves of fossil fuels and increasing environmental pollution have jointly necessitating the exploring of some alternative to the conventional liquid fuels, vegetable oils have been considered as appropriate alternatives to the conventional liquid fuels, vegetable oils have been considered as appropriate alternative due to their prevalent fuel properties. It was thought of as feasible option quite earlier. However, despite the technical feasibility, vegetable oils as fuel could not get acceptance, as they were more expensive than petroleum fuels. This led to the retardation in scientific

efforts to investigate the further acceptability of vegetable oils as alternate fuels. Later, due to numerous factors as stated above created resumed interest of researchers in vegetable oils as substitute fuel for diesel engines. In view of the potential properties, large number of investigation has been carried out internationally in the area of vegetable oils as alternate fuels.

As India is an agriculture based country, there is a wide scope for the production of vegetable oils (both edible and non-edible) from different oil seeds. Still lot of scope is left to explore the suitability of blends prepared from non-edible oils with an effort to bring down the engine pollution and to improve the engine life. In this background, the present work is carried out on blends of vegetable oils viz., cotton seed and Simarouba oils, using catalyst as heterogeneous (MgPO₄) and subject to the method of trans-esterification.

1.1 Biodiesel

Biodiesel which is derived from triglycerides by transesterification and from the fatty acids by esterification has attracted considerable attention during the past decade as a renewable, biodegradable, eco-friendly and non-toxic fuel. Several processes for biodiesel fuel production have been developed. Biodiesel is recently used as a substitute for petroleum based diesel due to environmental considerations and depletion of vital resources like petroleum and coal. The possible use of renewable resources as fuels and as a major feedstock for the chemical industry is currently gaining growth. Further, as petroleum is a fast depleting natural resource, an alternative renewable way to petroleum is a necessity. Now serious efforts are being made on the production and utilization of biodiesel in India. Methyl esters are clean burning fuel with no sulphur emission. Although its heat of combustion is slightly lower than that of the petrodiesel, there is no engine adjustment necessary and there is no loss in efficiency.

The transesterification reaction is represented by the general equation as



If methane is used in this process it is called Methanolysis. Methanolysis of glyceride is represented as below:

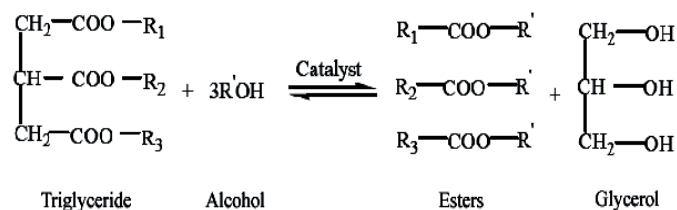


Figure 1: Transesterification of triglycerides

The biodiesel has emerged as alternative for diesel fuel, due to renewable nature, better ignition quality, comparable energy content, higher density, better safety due to higher flash point. It is sulphur free, no aromatics, non-toxic, and oxygenated. These characteristics reduce the emission of carbon monoxide (CO), and hydrocarbon (HC) in the exhaust gas as compared with petroleum diesel.

1.1.1 Vegetable Oils as Diesel Engine Fuels

Vegetable oils have become more attractive recently because of their environmental benefits and the fact that it is made from renewable resources. More than 100 years ago, Rudolph Diesel tested vegetable oil as the fuel for his engine. Vegetable oils have the potential to substitute for a fraction of the petroleum distillates and petroleum based petrochemicals in the near future. Vegetable oil fuels are not now petroleum competitive fuels because they are more expensive than petroleum fuels. However, with the recent increases in petroleum prices and the uncertainties concerning petroleum availability, there is renewed interest in using vegetable oils in Diesel engines. The diesel boiling range material is of particular interest because it has been shown to reduce particulate emissions significantly relative to diesel. There are more than 350 oil bearing crops identified, among which only sunflower, safflower, soybean, cottonseed, rapeseed and peanut oils are considered as potential alternative fuels for Diesel engines.

The benefits of using vegetable oil as diesel fuel are,

- Liquid nature-portability
- Ready availability
- Renewability
- Higher heat content (about 88% of Diesel Fuel)
- Lower aromatic content

- Biodegradability.

1.1.2 The Disadvantages of Vegetable oils as Diesel Fuel

The major problems of using vegetable oil as diesel fuel are higher viscosity, lower volatility and the reactivity of unsaturated hydrocarbon chains. Although short-term tests using neat vegetable oil showed promising results, problems appeared only after the engine had been operating on vegetable oil for longer periods of time. The high fuel viscosity in compression ignition causes the major problem associated with the use of pure vegetable oils as fuel for Diesel engines. All the vegetable oils are extremely viscous, with viscosities ranging 10-20 times greater than diesel fuel.

The major problem in direct use of vegetable oils as fuel into C.I engines is their higher viscosity. It interferes with the fuel injection and atomization and contributes to incomplete combustion, nozzle clogging, excessive engine deposits, ring sticking, contamination of lubricating oil, etc. The problem of higher viscosity of vegetable oils can be overcome to a greater extent by various techniques, such as heating, dilution, emulsification and esterification.

1.1.3 Biodiesel as an Alternative Fuel

In the past several decades, it has been found that biodiesel (Esters derived from Vegetable oils) is a very promising one. The most common blend is a mix of 20% biodiesel. And 80% petroleum diesel, called "B20".

The widespread use of biodiesel is based on the following advantages:

- Biodiesel is potentially renewable and non-petroleum-based
- Biodiesel combustion produces less greenhouse gases
- Biodiesel is less toxic and biodegradable
- Biodiesel can reduce tailpipe emissions of PM, CO, HC, air toxics, etc

Biodiesel also has some negative attributes.

- Lower heating value, higher viscosity
- Lower storage stability, material compatibility issue
- Slightly higher NO_x emission
- Little modifications are needed for the traditional CI engine to burn biodiesel

Among the above attributes of biodiesel, the higher NO_x emissions from biodiesel fuelled engines are a major concern due to more and restrict regulations, and therefore it serves as the major motivation of this work.

2. LITERATURE SURVEY

Fossil fuels are widely used as transportation and machinery energy source due to its high heating power, availability and quality combustion characteristics, but its reserve is depleting day by day. The diesel engine was invented by Dr. Rudolph Diesel and it was run by peanut oil at the Paris Exposition in the year 1900 [1]. So it has been established from then that, high temperature of diesel engine is able to run on variety of vegetable oils [2]. Today diesel-powered vehicles represents about one-third of the vehicles sold in Europe and the United States and it is being predicted that the sales of diesel run automobiles will rise from 4% in 2004 to 11% by 2012[3]. However, the use of raw vegetable oils as fuel may give rise to a variety engine problem, such as coking of injectors on piston and head of engine, carbon deposits on piston and head of engine and also excessive engine wear. In order to overcome these problems, many researchers had recommended the use of transesterified vegetable oils that can greatly reduce the viscosity of the oil and this transesterified vegetable oil is termed as biodiesel. Biodiesel (Greek, bio, life + diesel from Rudolf Diesel) refers to a diesel-equivalent, a processed fuel derived from a biological source [4, 5]. Southeast Asian countries mainly focus on export; India and China are putting forth their biofuel programs to keep up with their bullish economic growth and to reduce petroleum dependency [6]. Simarouba is a medium sized evergreen tree (height 7-15 meters) with tap root system and cylindrical stem; simarouba seeds contain 60-75% oil that can be easily refined, bleached, deodorized, and fractionated. The majority of fatty acids in simarouba seed oil consists of palmitic acid (10.90%), stearic acid (25.60%), linoleic acid (3.30%), oleic acid (59.10%), linoleic acid (3.30%), diene (0.13) and triene (0.002)[7]. Biodiesels has similar combustion characteristics as diesel and also the base catalyst performs better than acid catalyst and enzymes. The emission of oxides of nitrogen from the engine to be higher on the all fuel blends as compared to diesel [8]. The tree born oil like simarouba glauca is the most potential species to produce biodiesel in India which could offer opportunity the generation of rural employment [9]. All the properties which are tested in the case of simarouba oil are in the range of ASTM biodiesel standards and this can be promising factor to use Simarouba seeds as one of the biodiesel source [10]. Cotton seed oil is extracted from the seeds of the cotton plant of various species, mainly *Gossypium hirsutum* and *Gossypium herba-ceum*, which are grown for cotton fiber. Cotton plant grows mainly in China, the United States, and Europe. Crude cotton seed oil contains several types of non-glyceride materials, such as gossypol, phospholipids, sterols, resins, carbohydrates, and related pigments. Cotton seed oil has a density that ranges from 0.917 g/cm³ to 0.933 g/cm³. The seed contains 17–25 wt. % oil. The fatty acid composition of cotton seed oil is mainly linoleic (55.2–55.5%), palmitic (11.67–20.1%), and oleic acids (19.2–23.26%) [11]. Cottonseed oil has highest linoleic acid percentage (about 55.2%) i.e., poly-unsaturation compared to others which affects physical and thermal properties of biodiesel[12]. a slight

increase in brake thermal efficiency with simarouba blend and concluded that without any modification in engine we can save diesel fuel for certain extent without any compromise with standard performance characteristics and in future simarouba biodiesel can be a best alternative fuel which can replace the diesel[13]. Due to Better conversion rate and fuel properties satisfies the ASTM standard, Mahua oil Methyl Ester (MOME) using heterogeneous base catalyst i.e. calcinated Di- Magnesium phosphate is safer and can certainly be considered as a potential alternative fuel[14].

3. HETEROGENOUS TRANSTERIFICATION

In conventional industrial biodiesel processes, the methanol transesterification of vegetable oils (edible and non edible oil) is achieved using a homogeneous catalyst system operated in either batch or continuous mode. In most cases the catalyst is sodium hydroxide or potassium hydroxide. It is recovered after the transesterification reaction as sodium or potassium methylate and sodium soaps in the glycerol phase. An acidic neutralization step with, for example, aqueous hydrochloric acid or sulphuric acid is required to neutralize these salts or sometimes water. In that case glycerol is obtained as an aqueous solution containing sodium chloride. Depending on the process, the final glycerol purity will be about 80% to 95%. When sodium hydroxide is used as catalyst, side reactions forming sodium soaps generally occur. This type of reaction is also observed when sodium methylate is employed and traces of water are present. The sodium soaps are soluble in the glycerol phase and must be isolated after neutralization by decantation as fatty acids.

In addition to this saponification issue, homogeneously catalyzed transesterification, whether an acid or base catalyst is used, suffers some drawbacks in terms of process integrity. The first drawback is corrosion of the reactor and pipelines by dissolved acid/base species, which inevitably raises the material cost for process construction. The second is the impossibility of catalyst recovery from the reactant-product mixture. Catalyst separation can only be achieved by neutralizing the remaining catalysts and disposing of them at the end of the reaction, which raises problems with environmental pollution. A third drawback of homogeneously catalyzed transesterification is the limitation in establishing a continuous process. For these reasons, the heterogeneously catalyzed process, especially using solid base catalysts, has been studied continuously for the last decade. Homogeneous catalyzed process is illustrated in figure 2.

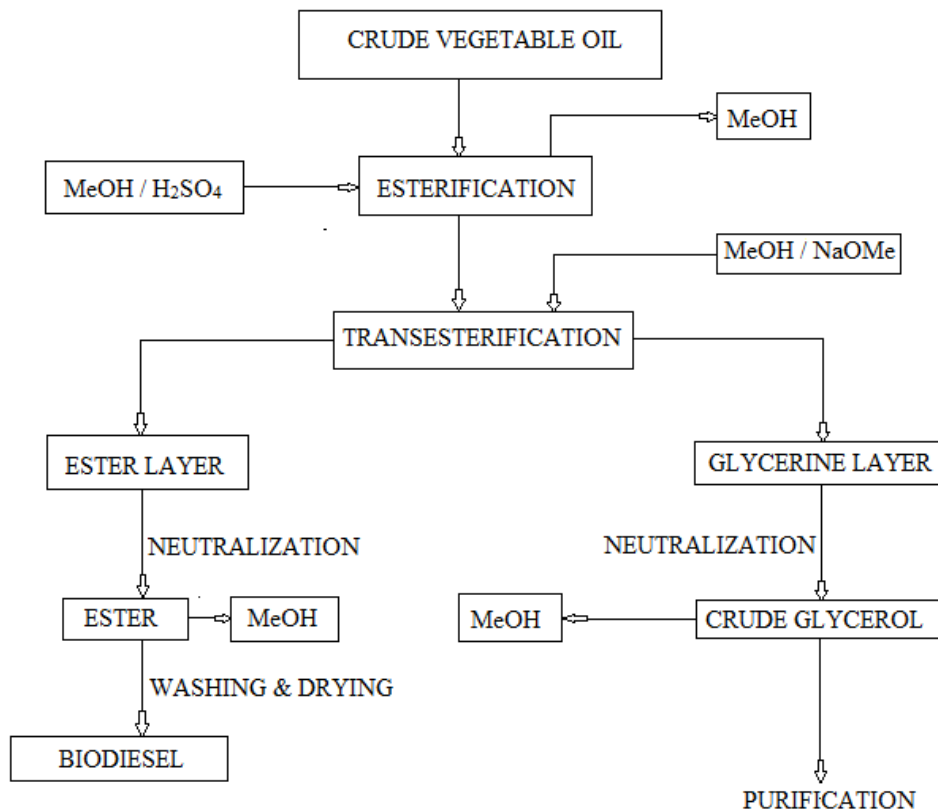


Figure 2: Global scheme for a typical continuous homogeneous catalyzed process.

To avoid catalyst removal operations and soap formation, much effort has been expended on the search for solid acid or basic catalysts that could be used in a heterogeneous catalyzed process. Some solid metal oxides such as those of tin, magnesium, and zinc are known catalysts but they actually act according to a homogeneous mechanism and end up as metal soaps or metal glycerates. So a new continuous process is described, where the transesterification reaction is promoted by a completely heterogeneous catalyst.

3.1 Heterogeneous base catalyst- Magnesium Phosphate

Heterogeneous catalyst has become more popular due to the main advantage of easily separation and purification of final products. These catalysts are less corrosive in nature hence environmental friendly. For a solid catalyst to be ideal, it should have high stability. Magnesium phosphate is a general term for salts of magnesium and phosphate appearing in three form, Monomagnesium phosphate, dimagnesium phosphate, and Magnesium phosphate tribasic. Calcinated magnesium phosphate is used as a heterogeneous base catalyst for biodiesel production. Figure 3 shows the flow diagram of bio-diesel production and use.

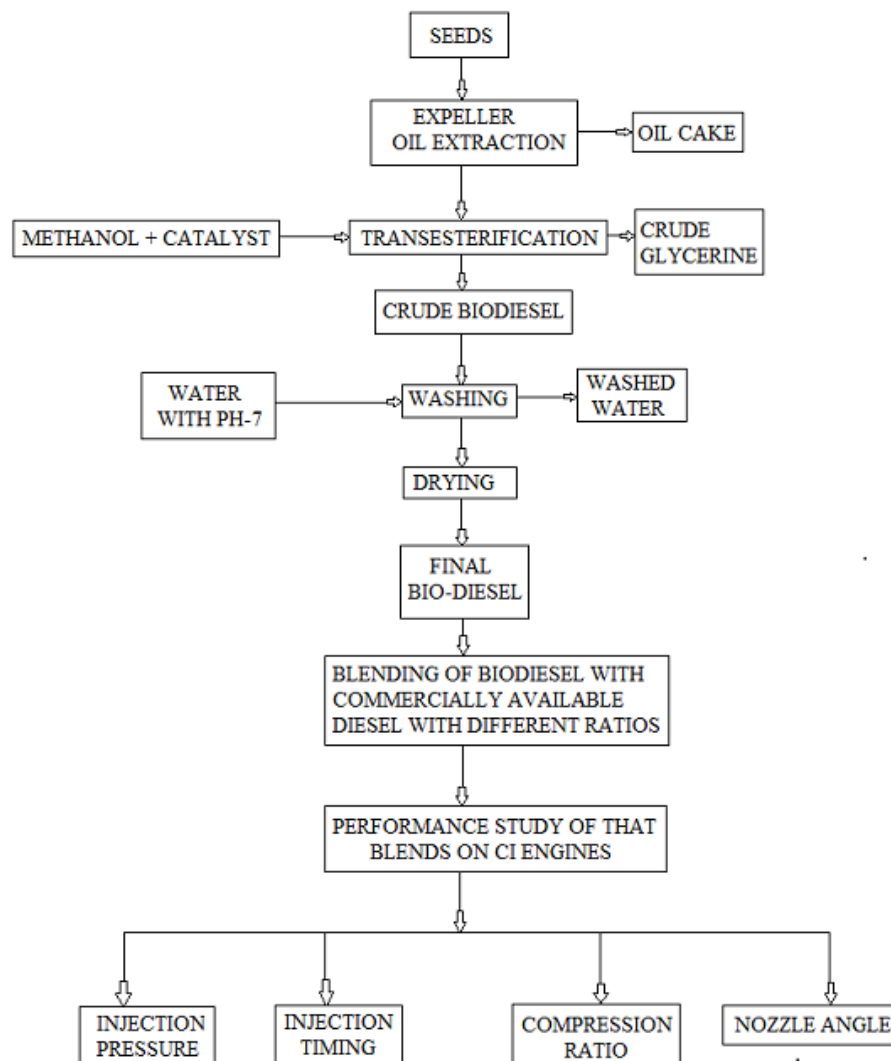


Figure 3: Flow chart of bio-diesel production and use

4. PREPARATION, CHARACTERIZATION OF COTTONSEED AND SIMAROUBA BLEND(B₅₀₋₅₀)

In this section, preparation, characterization of blend (B₅₀₋₅₀) is discussed in detail. After trans-esterification different properties of Bio-Diesel viz. kinematic viscosity, flash and fire point, corrosion testing, specific gravity and density are evaluated and compared with ASTM standards, to check the suitability of blend for use along with Diesel.

4.1 Gas Chromatography (GC) test:

After the preparation of the blend B₅₀₋₅₀, it is necessary that the sample is subjected to fatty acid composition test. This test is followed by bio-diesel production process, either single stage or double stage. The process selection is based on the presence of free fatty acid content in the raw oil. If the free fatty acid FFA content of the raw oil is less than 4%, single stage process has to be undertaken. Or if the free fatty acid content of the raw oil is more than 4%, double stage process has to be undertaken. Hence the determination of the free fatty acid content of the raw oil becomes the most critical aspect of the bio-diesel manufacturing. This was done by gas chromatography (GC) and the results are tabulated in Table 1.

Table 1: Gas chromatography (GC) results

| <i>S.No</i> | <i>Parameter</i> | <i>Result</i> |
|-------------|------------------|---------------|
| 1 | Palmitic acid | 17.93% |
| 2 | Stearic acid | 12.05% |
| 3 | Oleic acid | 37.06% |
| 4 | Linoleic acid | 28.52% |
| 5 | Lenolenic acid | 1.13% |
| 6 | Arachidonic acid | 2.65% |
| 7 | Behenic acid | 0.39% |
| 8 | Erucic acid | 0.17% |
| 9 | Lignoceric acid | 0.10% |

Determination of free fatty acid (FFA) content in raw oil

The following steps are necessary to determine the FFA content in raw oil.

Step1: Preparation of 0.1Normal (0.1N) NaOH solution:

4 grams of NaOH is weighed & transferred in to the conical flask containing 1 liter of water. Dissolve NaOH completely by constant stirring to get the 0.1N NaOH solution. (With NaOH the molecular weight is 40 so a 0.1N solution contains 4g per liter).

Step2: Titration and calculation of free fatty acid content in raw oil:

Take 25ml of 0.1N NaOH solution in the burette and then take 10 grams of blended cotton seed and simarouba oil, in a conical flask, add 50ml of Isopropyl alcohol into the conical flask and also add 5-6 drops of Phenolphthalein as indicator and shake well. This is titrated against the 0.1N NaOH solution until it turns pink color, this is the indication of end point and by using the formula we can find FFA content in the oil.

Step3: FFA calculation:

$$\text{FFA Content} = \frac{28.2 \times \text{Normality of NaOH} \times \text{Titration value}}{\text{weight of the oil}} \quad (2)$$

$$= 4.512$$

Note that the above equation (2) contains 28.2 which is the molecular weight of oleic acid divided by ten. Oils are not made of only oleic acid hence this formula results in small errors, normally accepted. Based on the available chart for FFA of 4.512 we have to add 1.25ml of H₂SO₄ to reduce the FFA in esterification process.

4.2 Esterification

In the Esterification process the excess free acid gets reacted. The remaining acid content in the oil undergoes transesterification. So this method is effective for oils that contain high free fatty acid (FFA) content. Hence the selection of acid catalyst is very important. The aim of esterification reaction is to remove water during processing otherwise seriously hurt the reaction conversions. The esterification reaction is shown below:





Figure 4: Experimental set for Esterification and Transesterification

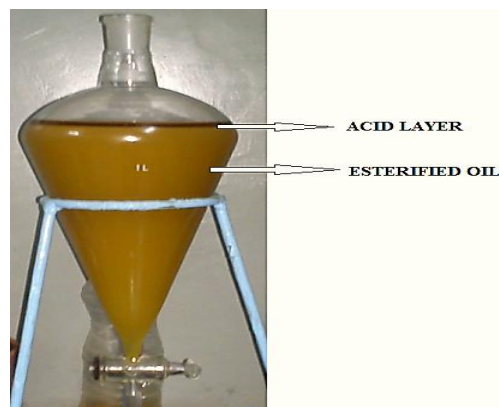


Figure 5: Settling of esterified oil

During the process 150ml of methanol + sulphuric acid was taken based on the FFA Chart(1.25 ml). Blended Cotton seed and Simarouba oil was heated till 65°C. After oil attained 65°C, the above mixture was poured in to the 3 neck flask ensuring necessary water circulation arrangement(Fig.4). Then the mixture was agitated in the reaction vessel (3-Neck flask) at 65°C for 1.5hrs. The mixture was then transferred to a separating funnel and allowed to settle for at least 2 to 3 hours. Acid layer will rise to the top as black layer as shown in the figure 5. The bottom layer to 3-Neck flask is separated by draining the top acid layer. The sample of the bottom layer was taken from the 3-Neck flask and measures the new FFA. After esterification FFA is measured once again following the same procedure as reported, Titration value was found to be 7, while the new FFA =1.974. Hence trans-esterification can be done.

4.3 BIODIESEL PRODUCTION BY HETEROGENEOUS TRANSESTERIFICATION:-

Biodiesel production by heterogeneous trans-esterification involves the following steps.

4.3.1 Catalyst preparation by calcination method

50g of dibasic magnesium phosphate trihydrate ($MgHPO_4 \cdot 3H_2O$) was taken in a hot china dish and made a paste with deionized water as shown in figure 6. The paste was dried in a hot air oven at 120 °C for 24 hrs for removing the moisture content present in the mixture. Dried magnesium phosphate dehydrate trihydrate was taken out from the furnace and crushed into fine particles. These fine particles of magnesium phosphate was further taken in a silica crucible and placed in muffle furnace and heated to about 5 hours by maintaining the temperature of 600°C. Thus, the calcinated Dimagnesium phosphate ($Mg_2P_2O_7$) catalyst was prepared for the transesterification reactions,



Figure 6: Photograph of catalyst preparation and the Muffle Furnace

4.3.2. Transesterification:

Transesterification also called alcoholysis, is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis, except that an alcohol is employed instead of water. Suitable alcohols include: methanol,

ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are utilized most frequently. This process is widely used to reduce the viscosity of triglycerides, thereby enhancing the physical properties of fuel and improve engine performance. Thus fatty acid methyl ester (also known as biodiesel) is obtained by trans-esterification.. **The Yield after this process was found to be 91% of biodiesel.** Figure 7 shows the flow chart for Blended Cotton seed and Simarouba oil trans-esterification catalyzed by calcinated Magnesium phosphate.

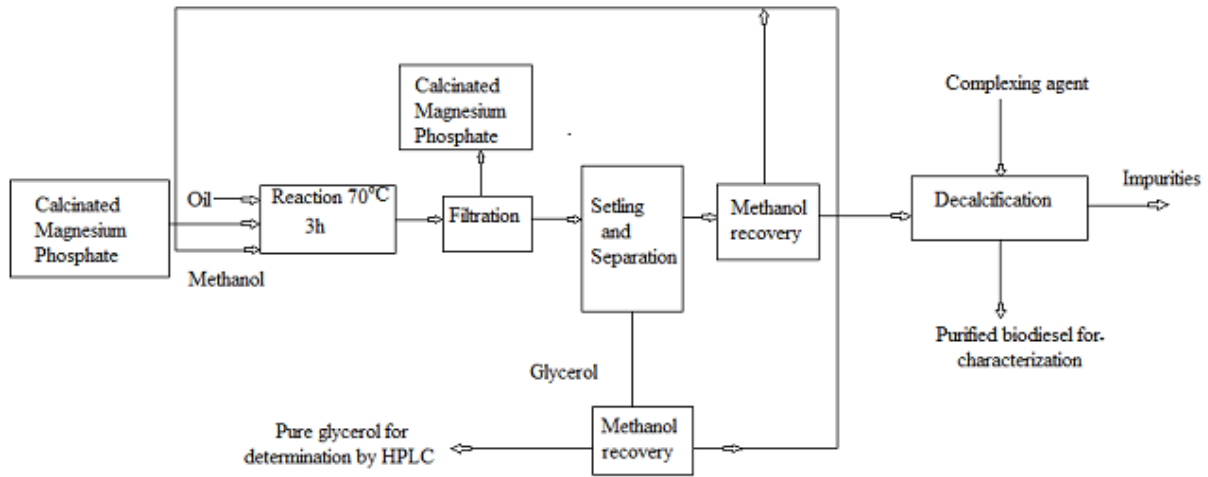


Figure 7 : Flow chart for Blended Cotton seed and Simarouba oil transesterification catalyzed by calcinated Magnesium phosphate



Figure 8: Transesterification setup

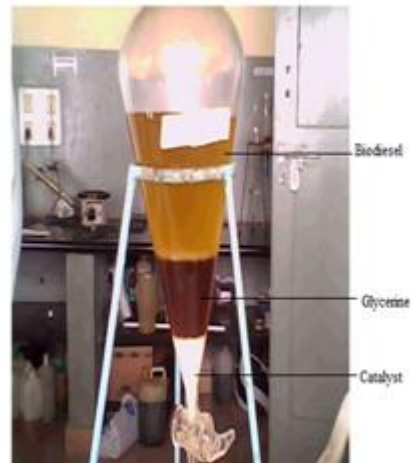


Figure 9: Transesterified Bio-diesel with three layers

Figure 8 shows the Transesterification set-up with Transesterified bio-diesel layers formed (Figure 9) . Following are the transesterification process parameters.

1. Methanol to oil molar ratio : 9:1
2. Amount of calcinated Magnesium Phosphate catalyst : 2 % (w/v)
3. Reaction Temperature : 70°C
4. Reaction Time : 3 hours

4.4.3. Recovery of Methanol from Bio-Diesel:

The Recovery of Methanol From Bio-Diesel is done as follows. Transfer the bio diesel in to 1liter round flask. Make the necessary arrangement for the distillation set up like heating, stirring by fixing the double wall condenser along with the recovery flask. Maintain the temperature around 70°C (boiling point 64.07°C).Methanol starts evaporating and undergoes condensation and can be collected at another end as shown in figure 10.

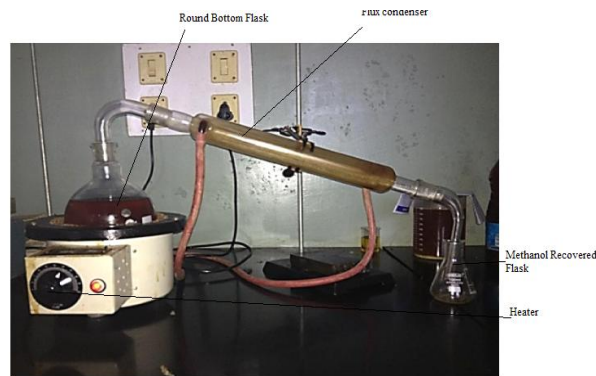


Figure 10: Experimental setup for Methanol recovery

4.4.4. Decalcification:

After recovery of methanol from Bio-diesel, decalcification is needed to remove impurities. Ethylene Di-amine tetra-acetic acid (EDTA) can be used as complexing agent. Bio-diesel is transferred in to the separating funnel and then 10gms of EDTA is added and mixed well. The mixture is allowed to settle for 1-2 hours, impurities will settle at the bottom in the form of solid that can be removed by filtering to get pure bio-diesel.

4.4.5 Properties of biodiesel

Once decalcification is done the following properties viz. flash and fire point, kinematic viscosity, corrosion, density and specific gravity of bio-diesel, are tested in the laboratory.

Figure 10 shows the Pensky- Martin Flash point apparatus used to determine lowest temperature at which the vapor of a combustible liquid can be made to ignite momentarily in air.



Figure 11: Photograph of Pensky Martin Flash point instrument

The variation of flash point for different biodiesel blends is shown in figure 12. For 100% blend (Referred as B₅₀₋₅₀), flash point is the highest at 149°C compared with flash point of around 56°C of diesel oil. However, it can be noticed that for practical range of blends B₁₀ to B₄₀ the flash point hovers between 64 °C - 77°C, which is safer than diesel oil.

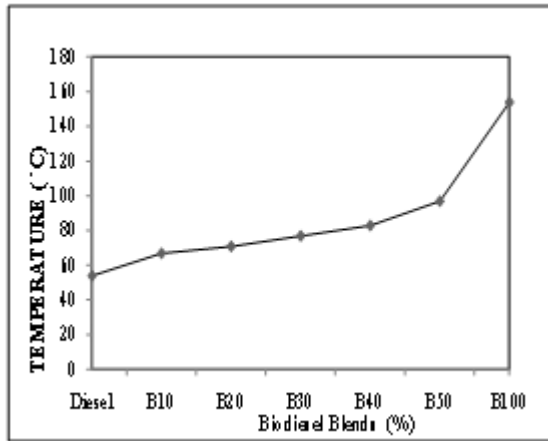


Figure 12: Flash point for different Blends and Diesel and diesel

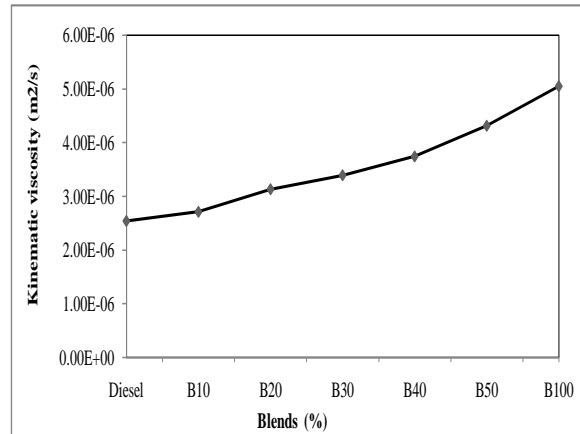


Figure 13: Kinematic viscosity of different Blends

The viscosity is important in determining optimum handling, storage, and operational conditions. It is significant because fuel flow characteristics decide whether adequate supply reaches injectors at different operating temperatures. High viscosity can cause fuel flow problems and lead to stall out. The viscometer bath is used to maintain correct constant temperature for estimating Kinematic viscosity of biodiesel. Figure 13 shows the variation of Kinematic viscosity of different blends of biodiesel at 40°C, obtained from Cannon–Fenske viscometer [tube no 100, direct type] bulb as shown in fig 13. The test bath was maintained at the temperature for a period of 20-30 minutes and the kinematic viscosity was calculated in Centistokes as,

$$\text{Kinematic viscosity (Cst)} = (\text{Number of seconds} \times \text{Standard factor of the bulb viscometer used for testing}) \quad (4)$$

$$\text{Kinematic viscosity for B}_{100} \text{ sample} = (212) \times (0.0238) = 5.0456 \text{Cst.} = 5.04 \times 10^{-6} \text{m}^2/\text{s}.$$

As evident from the figure 13, diesel has slightly better flowability advantage (kinematic viscosity, $v = 2.54 \times 10^{-6} \text{m}^2/\text{s}$) over the operating range B10- B40 (kinematic viscosity, $v = 2.71 \times 10^{-6} \text{m}^2/\text{s}$ - $3.74 \times 10^{-6} \text{m}^2/\text{s}$)

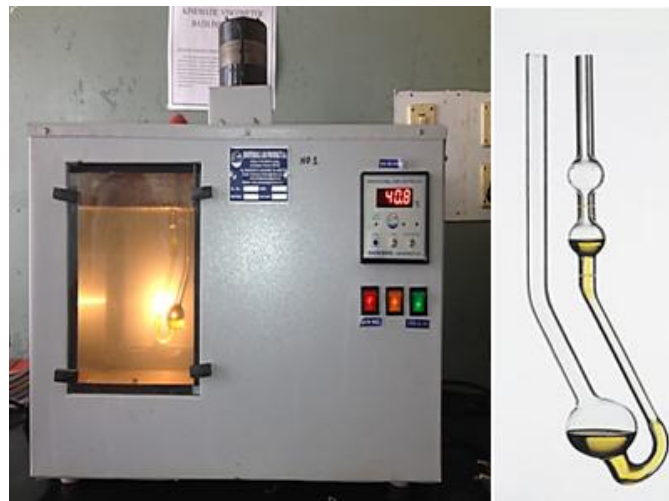


Figure 14: Photograph of Kinematic viscosity bath instrument with Cannon-Fenske tube

Acid and sulfur-containing compounds have the potential to cause corrosion in an engine system. The Copper strip corrosion test indicates (Fig. 15) the potential of biodiesel to affect the copper and brass fuel system part. Polished copper strip are immersed in the biodiesel sample and placed in a sample tube in a heated bath for several hours. The sample test strip is then compared to a standard test strip to determine the effect of biodiesel on the copper. Observations of tested Copper Strips, for biodiesel, diesel & its blends when compared with standard strip are shown in Table 3.

Table 3: Observations of tested Copper Strips for biodiesel, diesel & its blends when compared with standard strip

| S. No. | Blend | Observation |
|--------|--------|--------------|
| 1 | B10 | No Corrosion |
| 2 | B20 | No Corrosion |
| 3 | B30 | No Corrosion |
| 4 | B40 | No Corrosion |
| 5 | B50 | No Corrosion |
| 6 | B100 | No Corrosion |
| 7 | DIESEL | No Corrosion |



Figure 15: Copper strip corrosion instrument



(a)



(b)

Figure 16: Tested copper strip (b) compared with standard copper strip (a)

Figure 16 shows the evidence of no corrosion wherein the tested copper strip is compared with the standard specimen. From the table 3 and figure 16, it is evident that no blend of Bio-Diesel is corrosive in nature.

The density and specific gravity of Bio-diesel is tabulated in table 4, on the basis of testing on a hygrometer.. As expected, the density and specific gravity of the blend B₁₀- B₄₀ is higher by 0.86% to 3.32%, which is within the acceptable range for the fuel to use as an alternative.

Table 4: Specific Gravity & Density of biodiesel blends, & diesel

| S No. | Blend | Specific Gravity | Density (kg/m ³) |
|-------|------------------|------------------|------------------------------|
| 1 | B ₁₀ | 0.822 | 822 |
| 2 | B ₂₀ | 0.832 | 832 |
| 3 | B ₃₀ | 0.838 | 838 |
| 4 | B ₄₀ | 0.843 | 843 |
| 5 | B ₅₀ | 0.852 | 852 |
| 6 | B ₁₀₀ | 0.860 | 860 |
| 7 | Diesel | 0.815 | 815 |

American Society for Testing and Materials (ASTM) is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. The obtained fuel properties are compared with ASTM standards and it is found that all the values are within specified range as shown in the following table 5.

Table 5: Comparison of fuel properties with ASTM standards

| Sl.No | Properties | Standard | Range | Test value |
|-------|---------------------------------------|---------------|--|-------------------------|
| 1 | Flash point (°C) | ASTM D93 | >130 | 154 |
| 2 | Viscosity (m ² /s) at 40°C | ASTM D445 | 1.9×10 ⁻⁶ -6×10 ⁻⁶ | 5.0456×10 ⁻⁶ |
| 3 | Specific gravity | ASTMD4052 | 0.87-0.90 | 0.860 |
| 4 | Cloud Point | IS: 1448(P10) | -3 to 12 | 10 |
| 5 | Pour Point | IS:1448 (P10) | -15 to 10 | 5 |
| 6 | Ash Content (%w/w) | IS: 1448 (P4) | 0.5max | 0.014 |
| 7 | Carbon Residue | IS: 1448 (P8) | 0.05max | Nil |

5 CONCLUSION

In this work blend, a 50-50 blend of cotton seed and Simarouba seed oils was prepared. Biodiesel B₅₀₋₅₀ resulting out of cotton seed and Simarouba oil blend was subjected to Gas Chromatography (GC) and Free Fatty Acid (FFA) tests to check the suitability of bio-fuel blend as an alternate fuel to Diesel Engine. Based on the characterization of Bio-Fuel blend the following conclusions are drawn.

1. GC and FFA tests and subsequent esterification process confirmed only 1.974 ml of acid (FFA content) and hence paving way for trans-esterification process for further characterization.
2. Production optimization of biodiesel was done using heterogeneous (MgPO₄) as catalyst and the various properties of this blend are evaluated to explore its suitability as an alternate fuel
3. Property evaluation of bio-diesel blend viz. flash point, cloud and pour point, density and specific gravity, viscosity suggested that the proposed blend B₅₀₋₅₀ is a potential candidate to qualify as an alternate fuel for a CI engine.
4. Comparison of the various properties with ASTM prescribed standards further justifies the above conclusion, as the blend B₅₀₋₅₀ prepared from equal quantity of cotton seed and Simarouba oil is far superior or well within the prescribed range of ASTM standards.

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