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Synthesis of simarouba biodiesel and evaluation of its properties

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Abstract
In this work for the purpose of developing an alternate energy source that is capable to overcome the problems caused in the energy crisis in future, the biodiesel was prepared from simarouba glauca seeds by using a chemical reaction process called two stage transesterification. During preparation of the biodiesel, after removing of moisture content, the shell was removed manually and vegetable oil was extracted by using a mechanical expeller. In acid esterification, the concentrated sulphuric acid was used as catalyst whereas potassium hydroxide was used as catalyst in base transestrification process. The major properties of both vegetable oil and biodiesel were found out using laboratory equipments. The acid value, free fatty acid and kinematic viscosity of simarouba vegetable oil were reduced when it is converted into biodiesel. All other properties of biodiesel which were determined were found within ASTM standard limits.
Keywords: *Simarouba, Vegetable oil, Transestrification, Biodiesel, Acid value, Kinematic viscosity*

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I. INTRODUCTION

The continuous increase in the amount of consumption of fossil fuels as a result of the world's ever-increasing population and urbanisation has made the imminent depletion of these conventional fuel resources an inevitable fact. In addition, the emissions of greenhouse gases from such fossil fuels are continuously degrading the planet and contributing to global warming and also other problems associated with pollutant emissions. As a result, the situation necessitates the development of an alternative energy source that capable of overcoming the anticipated future energy crisis. Furthermore, if the energy source is renewable and clean, it will contribute to reduction of environmental issues. In their search for an alternative renewable energy source, scientists have proposed a number of ideas. Biodiesel-diesel blends as alternative energy sources have become popular and are getting the attention from many researchers [1].

Due to its numerous favourable properties, the development of biodiesel as a diesel fuel alternative has drawn a lot of attention over the years. But apart from being renewable and environmentally friendly, biodiesel with properties similar to diesel can be blended to desired proportions. Biodiesel is produced mainly through the transesterification of both edible and non-edible vegetable oils. In recent years, emphasis has been put on non-edible biodiesels because they are less expensive and have no impact on food supply [2]. Biodiesel which can be produced from renewable and domestic resources is nontoxic, biodegradable, free from aromatics and sulphur, simple to use and a a clean burning alternative fuel. Biodiesel does not contain petroleum, but it can be blended with petroleum diesel at any portion to create a biodiesel blend and it can be used in compression-ignition engines with minimal or no modification[3].

India is one of the largest importers of vegetable oil, producing approximately 7– 8 million tonnes of oil and importing approximately 5–6 million tonnes and is the world's largest cultivator of oil seeds. India has several areas with insufficient groundwater resources and also inadequate rainfall. As most of the cultivable land has already been occupied by traditional crops, the introduction of new oil seeds must be limited to those species that can grow in less favourable climatic conditions.

Simarouba glauca DC, also known as aceituno, bitter wood or paradise-tree is a medium-sized evergreen tree which can grow from 7 to 15 m tall and yields seeds with a high oil content (60%). It grows well in all kinds of well-drained soils with pH ranging from 5.5 to 8.0 and is found to establish in areas where annual rainfall occurs from 250 to 2,500 mm and temperatures reaching 45 °C. It can grow in dry or semi-dry areas and

can be planted in places in which no other plants of commercial value can grow. Since it grows well in places with little or no rain, it would be a great crop to promote as an oil seed crop in rural areas of the country. The Indian Council of Agricultural Research, New Delhi, first introduced Simarouba glauca to India in 1961. Because of its adaptability to a wide range of climatic and soil conditions, it has drawn a great interest for large-scale plantation for conservation of soil and reforestation programs. It is estimated that Orissa has the potential to produce 10 to 12 thousand tonnes of Simarouba seeds and more land is expected to be planted with the crop. Large-scale plantation has recently started in Karnataka, Andhra Pradesh and also other states of India. Under the current conditions of growing it for the purposes of conservation of soil, Simarouba glauca can yield an estimated 5 to 6 tonnes of seeds which is roughly equivalent to 1 tonne of oil per hectare [4]. So, here in this article, it is presented in detail the experimental procedure conducted for the synthesis of biodiesel from vegetable oil extracted from simarouba seeds by chemical reaction known as transesterification along with determination of its properties.

II. PREPARATION OF SIMAROUBA BIODIESEL

After getting the seeds, at first the moisture content is removed from the seeds and the shells are removed manually and using a suitable mechanical expeller the vegetable oil is extracted from kernels. The extracted vegetable oil from the seeds is as shown in the following Figure 1. Following are the required steps to convert simarouba vegetable oil into simarouba biodiesel.

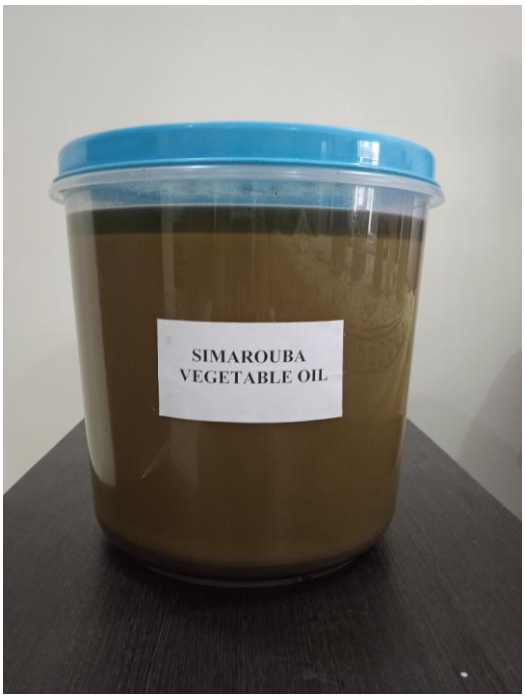

Figure 1. Simarouba vegetable oil

2.1 Determination of Acid value

After extraction of vegetable oil from kernels of simarouba seeds, the first step is the determination of acid value for the simarouba vegetable oil. Acid value for the simarouba vegetable oil is determined as the following.

$$\text{Acid value} = \frac{56.11 \times N \times V}{W}$$

Where, N – Normality of KOH or NaOH

N = 0.1 for KOH

V – Volume of solution in 'ml' in burette

W – Weight of vegetable oil sample in grams.

$$\therefore \text{Acid value} = \frac{56.11 \times 0.1 \times 0.7}{1.03} = 3.81$$

Acid value = 3.81

Since acid value of simarouba biodiesel is 3.81 which is high, acid esterification followed by transesterification processes are required to convert simarouba vegetable oil into simarouba biodiesel.

2.2 Purification of vegetable oil

During purification of vegetable oil, take 1 litres of simarouba vegetable oil in a container & filter it using cloth.

2.3 Dehydration

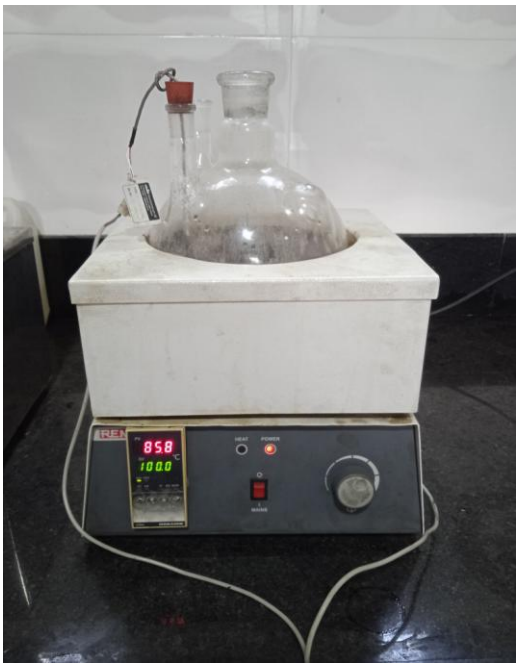

Figure 2. Biodiesel preparation setup

The above Figure 2. shows the biodiesel preparation setup which is called as 3 litres three neck round bottom flask taken for acid esterification and transesterification processes. After purification process, take that 1 liter of purified simarouba vegetable oil into 3 litres three neck round bottom flask and heat the oil till it reaches to 100 °C by setting to 100 °C along with using magnetic stirrer. This procedure is done to remove the moisture content of vegetable oil. After reaching 100 °C, the rise in temperature is stopped and then oil is allowed to cool along with stirring process up to 60°C. Stirring is done to cool heated oil at faster rate. The cooling process is stopped once oil reaches at 60 °C.

2.4 Acid esterification

Acid esterification process is carried out as the following

- Add 170 ml of methanol & 4 ml of H_2SO_4 to the dehydrated oil at 60°C. [Here, oil to methanol ratio maintained is 6:1 and H_2SO_4 is added at the rate of 0.4 (V/V) to the dehydrated oil at 60°C].
- Stir this mixture at 60°C for 60 minutes using magnetic stirrer along with using water condenser to trap the methanol. Afterwards this mixture is taken into separating funnel and it is kept here up to 30 minutes.
- After acid esterification process, methanol and precipitate (dust particles) is wasted and it is removed out from separating funnel. The remaining final product is taken for transesterification process.

2.5 Transestirification

Transestirification process is carried out as the following

- The same equipment which is used for acid esterification process is used for transesterification process.
- Take the final product into the same 3 litre three neck round bottom flask.
- Now, take 170 ml of methanol in a beaker and add 11 gm of KOH pallets after crushing into beaker and then add this solution to the final product of acid esterification process which is taken into 3 litre three neck round bottom flask.
- Stir the mixture well at 60°C constantly by setting at 60°C along with stirring by using magnetic stirrer for 60 minutes again using water condenser to trap the methanol.
- After 60 minutes, take mixture and pour it into separating funnel and leave it overnight to get the final product.

- Afterwards the glycerol which has high density is collected at the bottom of the separating flask and methyl ester (Biodiesel) of simarouba is at the top of separating funnel over glycerol. From this, glycerol is separated out by allowing glycerol out of separating funnel.
- At the top of separating funnel, the methyl ester remains. Methyl ester of simarouba is 900 ml.

2.6 Water wash treatment

Water wash treatment is carried out as the following

- For 1000 ml of biodiesel, take 1000 ml distilled water into 3 litre three neck round bottom flask and start heating the distilled water up to 50°C along with magnetic stirrer.
- Add this heated distilled water with biodiesel by using separating funnel and wait for 15 to 20 minutes so that the separation of excess catalysts, acid, methanol will be occurred at bottom of the separating funnel.
- Remove it by pouring into some container.
- Then remained oil product is once again is heated at 100°C to remove moisture content (Dehydration). Then it is allowed to cool. This is the final product of methyl ester of simarouba i.e. simarouba biodiesl which is shown by following Figure 3.

Figure 3. Simarouba biodiesel

2.7 Determination of Acid value of simarouba biodiesel determined after water wash treatment

After water wash treatment for the prepared simarouba biodiesel, an acid value is determined as the following.

$$\therefore \text{ Acid value } = \frac{56.11 \times 0.1 \times 0.7}{1.90} = 2.067$$

Acid value = 2.067

III. YIELD CALCULATIONS FOR SIMAROUBA VEGETABLE OIL AND SIMAROUBA BIODIESEL

3.1 From simarouba seeds to simarouba vegetable oil

The yield calculation of simarouba vegetable oil from its seeds is calculated as the following.

a) Quantity of simarouba seeds: 50 kg.
b) Quantity of vegetable oil converted from simarouba seeds: 9.78 litres.

$$\text{Yield } (\%) = \frac{9.78 \times 100}{50} = 19.56\ \%$$

Yield (%) = 19.56%

3.2 From simarouba vegetable into simarouba biodiesel

The yield calculation of simarouba biodiesel from its vegetable oil after water wash treatment is calculated as the following.

a) Simarouba vegetable oil taken for conversion it into simarouba biodiesel : 1000 ml
b) Biodiesel obtained after esterification and transesterification processes after water wash treatment: 900 ml

Yield calculation for biodiesel from Simarouba vegetable oil after water wash treatment

$$\text{Yield } (\%) = \frac{900 \times 100}{1000} = 90\%$$

Yield (%) = 90%

IV. DETERMINATION OF PROPERTIES

The determined properties for simarouba vegetable oil, biodiesel and their comparison with those of diesel fuel are listed in the following Table 1.

Table 1: Properties of simarouba vegetable oil, biodiesel and diesel fuel.

Properties	Simarouba vegetable oil	Simarouba biodiesel	Diesel	ASTM Standard
Flash Point (°C)	248	182	53	D 9358T
Fire Point (°C)	258	196	55	D 9358T
Kinematic Viscosity (m^2/sec) @ 40°C	37.11 x 10^{-6}	7.82 x 10^{-6}	2.09 x10^{-6}	D 445
Density (kg/m^3)	908	865	830	D 287
Calorific Value (kJ/kg)	38200	40047	42955	D 4809
Acid Value	3.81	2.067	0.6	D 6751
Free Fatty Acid	1.9	1.03	0.2	--

V. CONCLUSIONS

The following conclusions are drawn based on experimental observations,

1) The acid value of simarouba vegetable oil is reduced when it is converted into biodiesel from 3.81 to 2.067.
2) The properties determined for simarouba biodiesel were found comparable with those obtained for diesel fuel as per ASTM standards.
3) The yield value of simarouba vegetable oil from its seeds is 19.56%.
4) The yield value of simarouba biodiesel from its vegetable oil is 90%.

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