Performance & Analysis Of Pungamia Oil Blends With Diesel By Using Single Cylinder Diesel Engine

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Abstract— An ever increasing demand of fuels has been a challenge for today’s scientific workers. The fossil fuel resources are dwindling day by day. Biodiesel seem to be a solution for future. It is an environmental viable fuel. Several researchers have made systematic efforts to use plant oil and their esters (biodiesel) as a fuel in compression ignition (CI) engines. There is various types of raw material like Neem, Gingelly, Hemp, Jatropha curcus, Pungamia Pinnata (Karanja), Moha, Undi, Castor, Saemuruba, Cotton seed etc. An non-edible oil seeds and Various vegetable oils including palm oil, soybean oil, sunflower oil, rapeseed oil and canola oil have been used to produce biodiesel fuel and lubricants. Out of these Pungamia can be a definite source of raw material due to its easy availability in wild. Pungamia is a drought resistant, semi-deciduous, nitrogen fixing leguminous tree. It grows about 15-20 meters in height with a large canopy which spreads equally wide. After Transesterification of crude oil shows excellent properties like calorific value, iodine number, cetane number and acid value etc. Detail study intends to identify all advantages and disadvantages of pungamia as a sustainable feed stock for the production of Biodiesel equivalent to fossil fuel as per ASTM 6751-9B.

Keywords— pungamia oil, Single Cylinder, Diesel Engine

1. Introduction:

Energy crisis and environmental air pollution are of alarming concern worldwide. Exponentially increasing population, rapid growth of industrialization and the global trend of urbanization have totally disturbed the eco-balance and the balance of resources on earth. In particular, transport vehicles greatly pollute the environment through emissions such as CO, CO, NO, SO compounds consisting of organic unburnt or partially burnt HC and particulate emissions. Energy is an essential and vital input for economic activity. Building a strong base of energy resources is a pre-requisite for the sustainable economic and social development of a country. Indiscriminate extraction and increased consumption of fossil fuels have led to the reduction in underground based carbon resources. Further environmental degradation due to fossil fuel combustion includes Global warming, Ozone depletion, Acid precipitation etc. resulting in gradual increase in global temperature, acidification of lakes, streams and ground waters, damage to fish and aquatic life, damage to forests and agricultural crops and deterioration of materials. In addition, with the rising prices of crude oil and petroleum products in the world market and increasing dependence on imports, countries like India are becoming more vulnerable in the matters of energy security.

The entire amount is imported from Kuwait, Saudi Arabia, the United Arab Emirates and India costing over $2 billion. Demand for diesel surged by around 15 percent in recent months due to its increased use in captive generators in industries, commercial establishments and apartments as the country has been hit by power shortfall. Higher consumption of diesel, which accounts for approximately 60 percent of total import of petroleum products, will create a fresh pressure on the country’s fuel import bill this fiscal. Diesel is also used in the irrigation pumps and in the transportation sector. To meet the increasing demand of diesel, biodiesel may be an alternative source. The production of the oil seeds such as mustard, groundnut, linseed, castor, coconut and sesame is ~384115 Mtons/year, in which Pungamia seeds are produced around 16000 Mtons/year. The present number is not satisfactory for the production of biodiesel from Pungamia oil in Bangladesh. Additional Pungamia can be grown on a massive scale in the unused lands, which accounts around 0.32 million hectare and in that case Pungamia oil can be considered as an alternative source for biodiesel production. Pungamia oil is mainly composed of triglycerides of the singly saturated oleic acid (55%), doubly saturated linoleic acid (34%), palmitic acid (11.65%) and stearic acid (7.5%). Because of its excellent antioxidant property, sesame oil has an excellent self life. Moreover, it is a non drying oil and highly stable rarely turning rancid in hot climates.

In the present paper biodiesel has been prepared from sesame oil by base catalyzed Transesterification reaction with methanol. Effect of different reaction parameters such as Methanol/Oil molar ratio and catalyst concentration has been studied and optimum parameters have been found. Kinetics of the Transesterification reaction has been studied and pseudo first order kinetic equation was proposed. The experimental data was fitted to this model.

2. MATERIALS AND METHODS

2.1 Chemicals

Methanol (99-100%), ethanol (99-100%), sodium hydroxide pellets (96%), potassium hydroxide pellets (>84%), phenolphthalein (pH 8.2 - 9.8), starch, acetone (99%), benzene, sodiumthiosulfate (99.0%), n-Hexane (96%), hydrochloric acid (37%) , sulfuric acid (98%), isopropanol, iodine, sodium iodide, glacial acetic acid, bromine, carbon tetrachloride, phosphoric acid (85%), s-Diphenylcarbazide, Potassium Dichromate etc.
were purchased from Merck, Germany. All the chemicals used were analytical reagent grade.

2.2 Extraction of oil

Pungamia seeds were collected from local market. Oil from the seed was extracted by mechanical press. A vertical, manual operated, cylindrical (4.3 cm ID) mechanical press was constructed which have a spiral screw that conveys the mass from the hoper to pressure raising area. Slow and continuous rotation of the press allows raising sufficient pressure for the extraction of oil. The spiral screw is used for random mixing and size distribution. Oil drainage nozzles are located in the face of the expeller. At first the sesame seed were smashed and then oil was extracted from the smashed mass. In that process, 20 mL solvents (n-hexane) was mixed with 50 gm of smashed Pungamia seed; then oil extracted from the seed. After oil extraction it was filtered and solvent was evaporated in rotary evaporator under vacuum at 60°C. The oil content of Pungamia seed was found 35% (v/w).

2.3 Synthesis of biodiesel by Transesterification

Biodiesel from Pungamia oil was synthesized by base catalyzed Transesterification reaction. The reaction was carried out at 60°C and atmospheric pressure under reflux for 90 minutes with vigorous stirring. Typically 50 gm of oil sample were placed in a two-necked 250 mL round bottom flask equipped with a reflux condenser. The flask was immersed in an oil bath with a temperature controller and magnetic stirrer. Sodium hydroxide pellets (1 wt % of oil) was dissolved in required amount of methanol. Methanol was used 6:1 molar ratio to oil. The sodium-methoxide solution was transferred into the reaction flask. After 90 minutes the reaction was stopped by adding required stoichiometric amount of concentrated hydrochloric acid and then the contents were cooled to room temperature. After the reaction period, the reaction product was allowed to stand 12-14 hour in a separatory funnel. Three separate layers were observed. Upper layer was excess methanol, middle layer was methyl ester (Biodiesel) and lower layer were a mixture of soap, crude glycerin and lye catalyst. The Biodiesel layer was separated and this layer was opaque as it contained some catalyst, methanol, triglyceride and soap. Biodiesel from Pungamia Oil.

Comparison of properties of diesel, Pungamia oil and its methyl ester Properties

<table>
<thead>
<tr>
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<th>Diesel fuel</th>
<th>Pungamia oil</th>
<th>Pungamia ester</th>
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</thead>
<tbody>
<tr>
<td>Density (kg/m³)</td>
<td>830</td>
<td>912</td>
<td>880</td>
</tr>
<tr>
<td>Kinematic Viscosity @ 40°C (cSt)</td>
<td>3.01</td>
<td>41.06</td>
<td>4.25</td>
</tr>
</tbody>
</table>

2.4 EXPERIMENTAL SET UP

The engine is operated at the rated speed of 1500 rpm for all the tests. For all the tests, the engine is started with diesel fuel and allowed to stabilize for 30 min. After the engine is warmed up, it is then switched to NOME diesel blends. For each experiment, three measurements are taken to average the data so as to determine the repeatability of the measured data and have an estimate of measured accuracy. At the end of test, the fuel is switched back to diesel and the engine is kept running for a while before shutdown to flush out the NOME diesel blends from the fuel lines and injection system. The performance parameter such as Brake Thermal efficiency (BTE) and brake Specific Energy Consumption (BSFC), combustion parameters such as cylinder pressure, rate of heat release and emission parameters such as like smoke intensity, HC, CO and NO emissions are measured for diesel fuel and NOME diesel blends. Finally, the test results are analyzed and compared with the diesel fuel.

3 RESULTS AND DISCUSSION

Transesterification is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglycerides of five non-edible oils react with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and
glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification. This esterified vegetable oil is called bio-diesel. Biodiesel properties are similar to diesel fuel. After esterification of the vegetable oils its density, viscosity, cetane number, calorific values are improved more. So these improved properties give good performance in CI engine. Physical and chemical properties are more improved in esterified vegetable oil because esterified vegetable oil contains more cetane number than diesel fuel.

3.1 BENEFITS OF TRANSESTERIFICATION

- Reduces the high viscosity of the oil
- Increases the volatility
- High cetane number
- No sulphur, No aromatics
- Best emission with oxidation catalysts
- High oxygen content (1%)
- Exorbitant lubricity

The structure of typical vegetable oil molecule is given below:

Here R1, R2 and R3 represent straight chain alkyl groups. Free fatty acids are also found in vegetable oils. The large molecular sizes of the triglycerides results in the oils having higher viscosity and low volatility compared to mineral diesel. Proportion and location of double bonds affects cetane number of vegetable oils.

Problems associated with vegetable oils during engine tests can be classified into two broad groups, namely, operational and durability problems. Operational problems are related to starting ability, ignition, combustion and performance. Durability problems are related to deposit formation, carbonization of injector tip, ring sticking and lubricating oil dilution. It has been observed that the straight vegetable oils when used for long hours tend to choke the fuel filter because of high viscosity and insoluble present in the straight vegetable oils. The high viscosity, polyunsaturated character, and extremely low volatility of vegetable oils are responsible for the operational and durability problems associated with its utilization as fuels in diesel engines. High viscosity of vegetable oils causes poor fuel atomization, large droplet size and thus high spray jet penetration. The jet tends to be a solid stream instead of a spray of small droplets. As a result, the fuel is not distributed or mixed with the air required for burning in the combustion chamber. This result in poor combustion accompanied by loss of power and economy.

3.2 Transesterification Reaction

The transesterification set up is shown in fig. The mixture was stirred continuously and then allowed to settle under gravity in a separating funnel. Two distinct layers form after gravity settling for 24 h. The upper layer was of ester and lower layer was of glycerol. The lower layer was separated out. The separated ester was mixed with some warm water (around 10% volume of ester) to remove the catalyst present in ester and allowed to settle under gravity for another 24 h. The catalyst gets dissolved in water, which was separated. Moisture was removed from this purified ester using silica gel crystals. The ester was then blended with mineral diesel in various concentrations for preparing biodiesel blends to be used in CI engine for conducting various engine tests. The process of transesterification brings about a drastic change in the density of pungamia oil and the pungamia oil methyl ester has almost similar density as that of mineral diesel.

3.3 Effect of catalyst concentration on transesterification

The conversion of pungamia oil to biodiesel is greatly affected by catalyst concentration. Biodiesel conversion was measured by both measuring the concentration of glycerin produced in reaction and the kinematic viscosity of the produced biodiesel. Methanolysis of sesame oil was carried out with NaOH as a catalyst at concentration range from 0.25 – 1.5 wt% of oil at 60 °C with oil/methanol molar ratio of 1: 6. The results are given in Fig. 3.
Fig. 3: conversion of sesame oil to biodiesel at different catalyst concentration [Reaction temp. 60 °C, oil / methanol molar ratio 1:6 and Reaction time 90 min under reflux with vigorous stirring].

From the Fig. 3, it shows that the lower catalyst concentration i.e. 0.25 wt% NaOH of oil was insignificant to catalyze when the conversion of pungamia oil to biodiesel was measured in terms of glycerin concentration and conversion was 87.2% from oil to biodiesel when measured in terms of kinematic viscosity. However 0.87 wt% NaOH of oil was optimal in the reaction both measurement with a conversion of 72% in terms of produced glycerin concentration and with a conversion of 98.3% in terms of kinematic viscosity in just 90 minutes. With the increase in concentration of catalyst, there was decrease in the yield of methyl ester.

This was in accordance with the result obtained by Dorado et al. (2004). and was due to the formation of soap in presence of high amount of catalysts, which increased the viscosity of the reactants and lowered the conversion. Conversion of triglyceride found by glycerin determination method was lower than that of determined by viscosity method. The lower conversion from the result was expected as considerable amount of glycerin was lost during the separation of glycerin layer and some of the glycerin remained in the biodiesel layer.

3.4 Properties of produced biodiesel

Properties of the produced biodiesel and comparison with biodiesel and petro-diesel standard are given in Table 1. The quality of biodiesel was determined by measuring some property such as cetane number which indicates ignition characteristic. Cetane number of biodiesel was slightly lower than standard value of biodiesel. But the cetane number of the blend of pungamia oil with petro diesel was higher than standard value of biodiesel. Flash point of the produced biodiesel was higher than petro-diesel which is safe for transport purpose[1]. Other properties such as kinematic viscosity, cloud point, pour point, density, pH, saponification value etc. were measured.

Fig. 4: Concentration of produced glycerin-Time curve for transesterification reaction.

4 CONCLUSION

Based on the results of this study, the following specific conclusions were drawn as after esterification of pungamia oil, the kinematic viscosity and specific gravity reduced to 9.6 mm²/s and 0.876 from 27.84 mm²/s and 0.912 respectively. However, the calorific value of esterified pungamia oil increased to 36.12 MJ/ kg, which is 14.42% lower than diesel and 5.86% higher than pungamia oil.Higher flash point of esterified pungamia oil and its blend with diesel made for safe storage and handling of these oils.

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