Production of Cotton Seed Biodiesel and Its Usage in a C I Engine with Methyl Ester and $A1_2O_3$ Additives

Basavaraj Ganiger and B. Yuvaraj

Abstract In this work, cotton seed crude oil was obtained from the dried seeds using mechanical device called expeller. The free fatty acid (FFA) of cotton seed crude oil was found higher so it was subjected to double stage transesterification process. The maximum yield of cotton seed biodiesel was found with optimized variables; catalytic concentration, molar ratio and reaction time. In addition to pure biodiesel usage the methyl ester (neat diesel) and Al_2O_3 nano particle additives were used to blend the biodiesel in different proportions. The properties of the blend made of 20% cotton seed biodiesel and 80% methyl ester and Al_2O_3 nanoparticles were found close to pure diesel properties. A single cylinder, four strokes diesel engine was tested at different loads by maintaining constant speed with cotton seed biodiesel and its blends with methyl ester and Al_2O_3. It is observed that comparatively higher brake thermal efficiency (BTE), lesser brake specific fuel consumption (BSFC) and higher exhaust gas temperature (EGT) for blend made of 20% cotton seed biodiesel and 80% methyl ester and Al_2O_3 nanoparticles.

Keywords Cotton seed · Mechanical expeller · Trans-esterification process · Methyl ester · Al_2O_3 · BTE · BSFC & EGT

Abbreviations

BSFC	Brake specific fuel consumption
BP	Brake power
BTE	Brake thermal efficiency
B20	20% Biodiesel
B20A30	20% Biodiesel with 30 ppm Nano particles

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B20A60	20% Biodiesel with 60 ppm Nano particles
B40A30	40% Biodiesel with 30 ppm Nano particles
B40A60	40% Biodiesel with 60 ppm Nano particles
Al_2O_3	Aluminum Oxide
CO	Carbon monoxide
CO2	Carbon dioxide
FFA	Free Fatty Acids
CNG	Compressed Natural gas
EGT	Exhaust gas temperature
RSM	Response Surface Methodology

1 Introduction

The depletion of fossil fuel attached with an increase in fuel charges has been directed the research for other alternatives such as biodiesel, ethyl alcohol and many renewable energies. A Biodiesel is an alkyl ester of fatty acids obtained from plants or animals. These fatty acids can be converted into short chain alcohols such as methanol and ethanol by the trans-esterification process [1]. Biodiesel has numerous advantages over conventional diesel with respect to renewability, nontoxicity, biodegradability etc. Biodiesel contains lesser amount of sulphur compounds and a higher flash point (>1300 °C), lower CO_2 and hydrocarbon emissions and also considerably lesser particulate matter [2].

Higher worth of crude oil and in the view of environmental pollution reduction, the biodiesel as an alternate fuel is extremely concern subject. The biodiesel is the demand of many Asian countries as an alternate fuel to substitute for costly crude oil. The utilization of vegetable oils for cookery purpose raises the matter of their disposal. The correct utilization of these oils is an advantageous by the biodiesel production. The vegetable oil alkyl radical organic compound might be one in all the nice sources for production of biodiesel that is an alternate fuel of diesel [3].

In addition to reduction of dependency on crude oil, biodiesel has a helpful social impact by encouraging farmers to produce oil crops and receive an income [4]. The oils from diverse sources have varying fatty acid compositions. The fatty acids have variations with respect to degree of unsaturation and the chain length. There is a growing interest on non- edible tropical crops such as Honge, Jatropha curcas etc. It is found that algae have oil productivities more than any land-based crops and can meet global demand for transport fuels [5, 14].

The biodiesel production process requires either base or acidic materials as catalysts. The Sodium methoxide, Sodium hydroxide and Potassium hydroxide are the most normally used catalysts. Depending on the alcohol triglyceride ratio, concentration, mixing and temperature base catalyzed reactions are quite faster. Compared to base catalysts, acid catalysts (sulfuric and phosphoric acids) reactions have been noticed to be slower [6, 15].

Low-emission fuels like fermentation alcohol, methyl ester and compressed natural gas (CNG) for diesel engines should be developed crucially [7–9]. Cheap oils can be used for C I engine if there is any shortage of crude oils. Biodiesel is popular because of its inexhaustibility, biodegradability and harmlessness. Methyl ester can be manufactured by trans-esterification process. The biodiesels have higher cetane number and free from foul smell [10–13].

2 Methodology

2.1 Biodiesel Production

The process of biodiesel production is having several steps as shown in Fig. 1. The

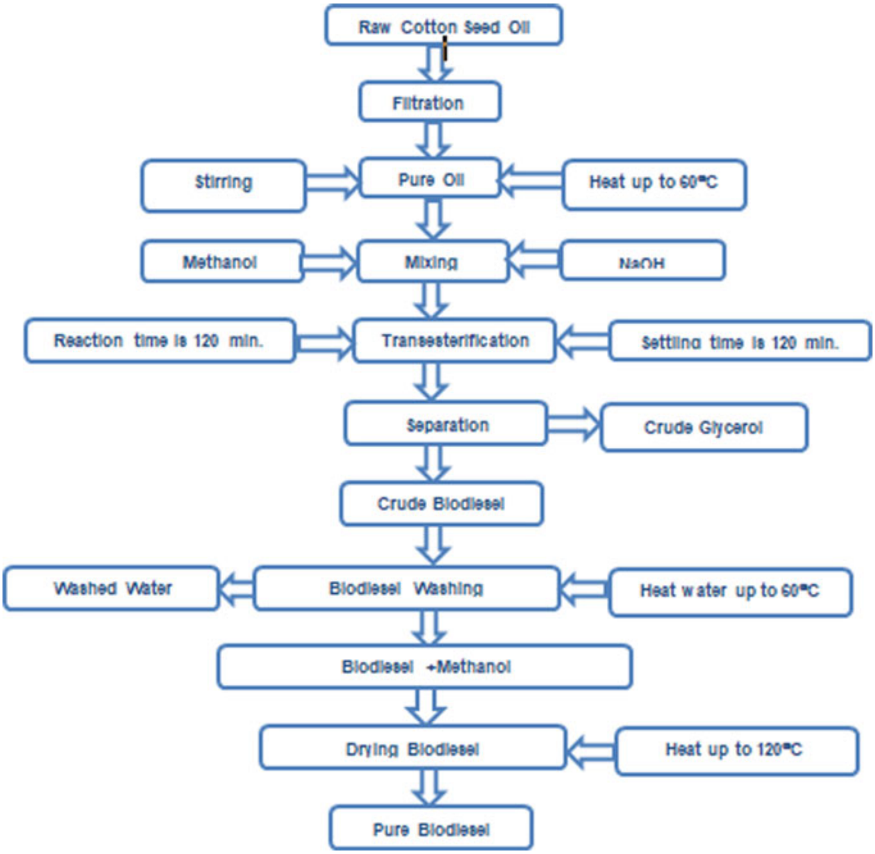

Fig. 1 Production of biodiesel from cotton seed oil

flow chart explains the biodiesel production from cotton seed oil by alkali base trans-esterification process. In this pretreated oil subjected to a trans-esterification process under the suitable alcohol generally methanol and catalyst at given temperature and reaction time. After the process, taken the reaction solution in a separating flask to separate glycerol formation and soap residuals. Based on their densities biodiesel, glycerol and residuals are separated in separating flask two hour later. Separated the glycerol and soap residual from the biodiesel and then carried water wash to the biodiesel and then heated the biodiesel above 100 °C.

50 kg cotton seeds were collected and mechanical expeller was used and got an oil yield of 25 percentages means, 250 ml of oil per kg of cotton seed. In the cotton oil production process it is necessary to remove some impurities by filtration. Since the free fatty acid content was found more, alkali acid trans-esterification was followed. The apparatus used in the biodiesel production has shown in Fig. 2.

The trans-esterification process was carried out by pouring one liter filtered cotton oil into three flasks and fixed a condenser to the flask and mixed 5.5 grams of Sodium Hydroxide (NaOH) and 250 ml methanol, solution was prepared. The solution was heated to 600 ºC using heater and simultaneously stirred regularly with magnetic

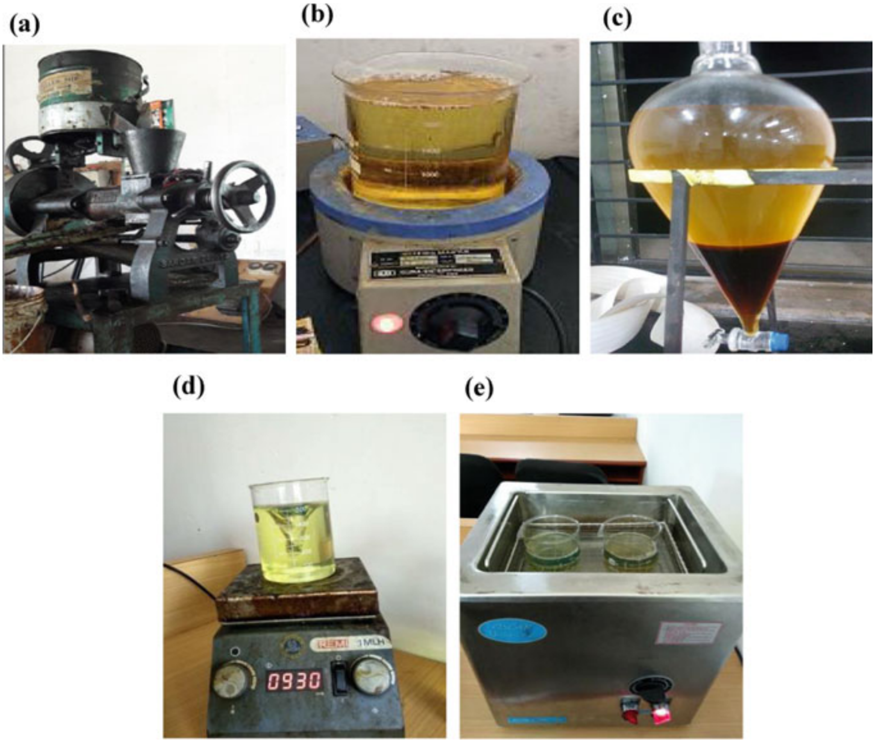

Fig. 2 Apparatus used in the Biodiesel Production; **a** Oil Expeller, **b** Oil Heater, **c** Separation Flask, **d** Magnetic Stirrer and **e** Sonicator

stirrer at speed 600 rpm. The solution was poured into a beaker. The solution was stirred for 2 hours to achieve appropriate reaction. The mixture was transferred into a separate flask and allowed to settle. After the 2 hours settling time in the separation flask two phases were formed; Methyl ester and Glycerol. The glycerol was removed from the separation flask then Poured 1 liter of hot water (600 ºC) into the separation flask for water wash. Also to separate soap content 4 to 5 times the water washing was repeated. The methyl ester from the separation flask was transferred to open measuring glass and heated using electrical radiator for around 1200 ºC. So methanol vaporized and only methyl ester remained in the flask. It is recorded that from 1 liter of cotton seed oil, 947 ml of biodiesel can be obtained.

2.2 Preparation of Biodiesel Blends with and Without Addition of Aluminum Oxide Nano Particle

Biodiesel extracted from the cotton seed oil is blended with diesel and aluminum oxide nano particles. The B20 (20% Biodiesel and 80% Neat Diesel) taken in a beaker and 0.03 grams of Al_2O_3 per 100 ml blend (30 ppm) was injected. The solution was placed on magnetic stirrer at constant speed and constant temperature of 400 °C for thorough mixing of added nano particles up to 1 hour. This Biodiesel blend with Al_2O_3 was used directly for combustion in diesel engine without any modification. Similarly the Al_2O_3 nano particles added in distinctive proportion of 30 ppm and 60 ppm for B20 (20% Biodiesel and 80% neat diesel), B40 (40% Biodiesel and 60% neat diesel) and B60 (60% Biodiesel ester and 40% neat diesel).

2.3 Experimental Details and Instruments Used

Performance characteristics were studied by using water cooled, single cylinder, 4 strokes diesel engine which had BP of 5.2 kW at 1500 rpm. The experimental set up has shown in Fig. 3. The experimental setup made in such way that by maintaining constant water flow to cool down the engine and heat transfer in the exhaust line. The engine specifications are listed in Table 1. An eddy current dynamometer was used to give load to engine and it was computer interfaced to record the digital data.

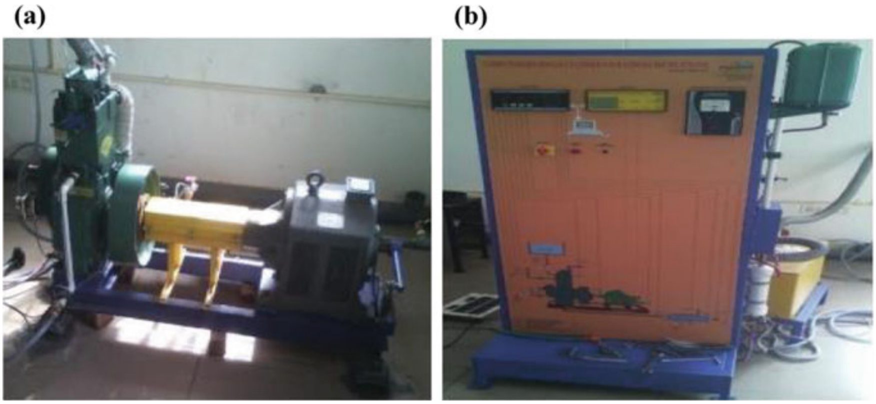

Fig. 3 Experimental set up; **a** Test rig and **b** Control unit

Table 1 Test engine specifications

Particulers	Details
Type of engine	4 stroke diesel engine
Engine make	Kirloskar TV1
Number of cylinder	Single
Engine capacity	661 cm^3
Compression ratio	16.7:1
Bore	87.5 mm
Stroke	110 mm
Brake power	5.2 kW@ 1500 rpm

3 Results and Discussions

3.1 Effect of Al_2O_3 Additive on Cotton Seed Oil Properties

The flashpoint of pure biodiesel is more compared to petro diesel but it is possible to reach the flash point of diesel by adding the aluminum oxide to biodiesel. From Fig. 4a-e, it can be observed that as biodiesel percentage increases in the blends there is an increase in flash point. Among blends B20A60 has flash point nearer to diesel (67 °C). Also the blend B20A60 has fire point nearer to diesel; 700 °C, viscosity nearer to diesel; 3.45 cSt.

Cotton seed biodiesel has maximum density of 900 kg/m^3 and Al_2O_3 has a maximum density of 3700 kg/m^3. It can be observed from Fig. 4 that addition of Al_2O_3 causes increase in the density of biodiesel. Among blends B20A60 has density close to Diesel; 833.8 kg/m^3. It can also be observed that as biodiesel percentage in blends increases there is a decrease in calorific value. It is because of the reason that biodiesel is an oxygenated fuel; its calorific value is less compared to diesel. Diesel

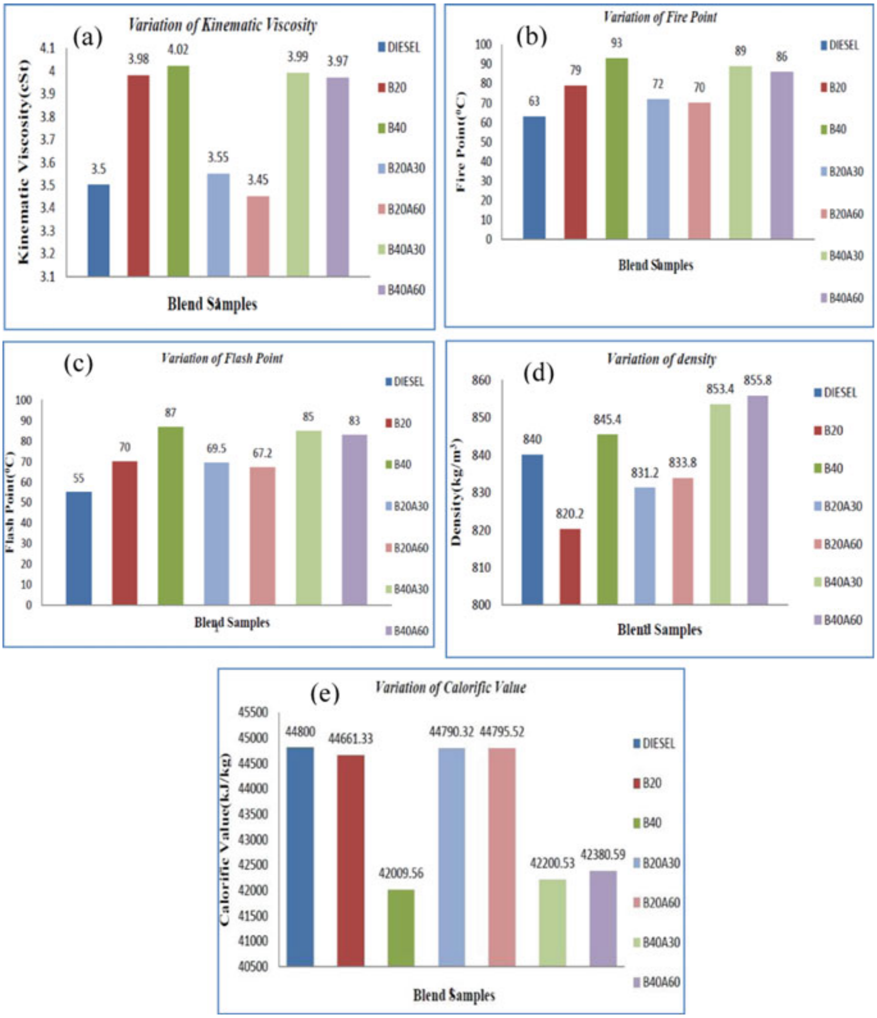

Fig. 4 **a–e** Comparison of fuel properties; **a** Flash point, **b** Fire point, **c** Viscosity, **d** Density and **e** Calorific value

has a highest calorific value of 44800 kJ/kg and B20A60 has calorific value nearer to diesel; 44795.52 kJ/kg.

3.2 *Effect of Al_2O_3 Additive on Engine Performances*

The performance parameters such as brake thermal efficiency, specific fuel consumption and exhaust gas temperature have been studied using neat diesel and biodiesel blends with and without catalysts and results have shown in Fig. 5a-f. Brake Thermal Efficiency (BTE) is a parameter that shows the amount of heat energy of fuel converted into mechanical energy. It can be observed that addition of Al_2O_3 to biodiesel and/or diesel blends resulted in an increase of BTE. Highest BTE was noticed for the blend B40A60 (48.18%). Even though the calorific value of blend B40A60 is less than diesel highest BTE was achieved because of better mixing of fuel and air and good combustion.

Brake specific fuel consumption (BSFC) is another parameter that measures the amount of heat energy of fuel converted into mechanical energy. The Al_2O_3 blended fuels have lower BSFC than blends without Al_2O_3 because at high temperatures it mixes properly with air, resulting in good combustion process, producing higher power output and reduced BSFC. Least BSFC of 0.0029 kg/kW-min noticed with the blend B20A60.

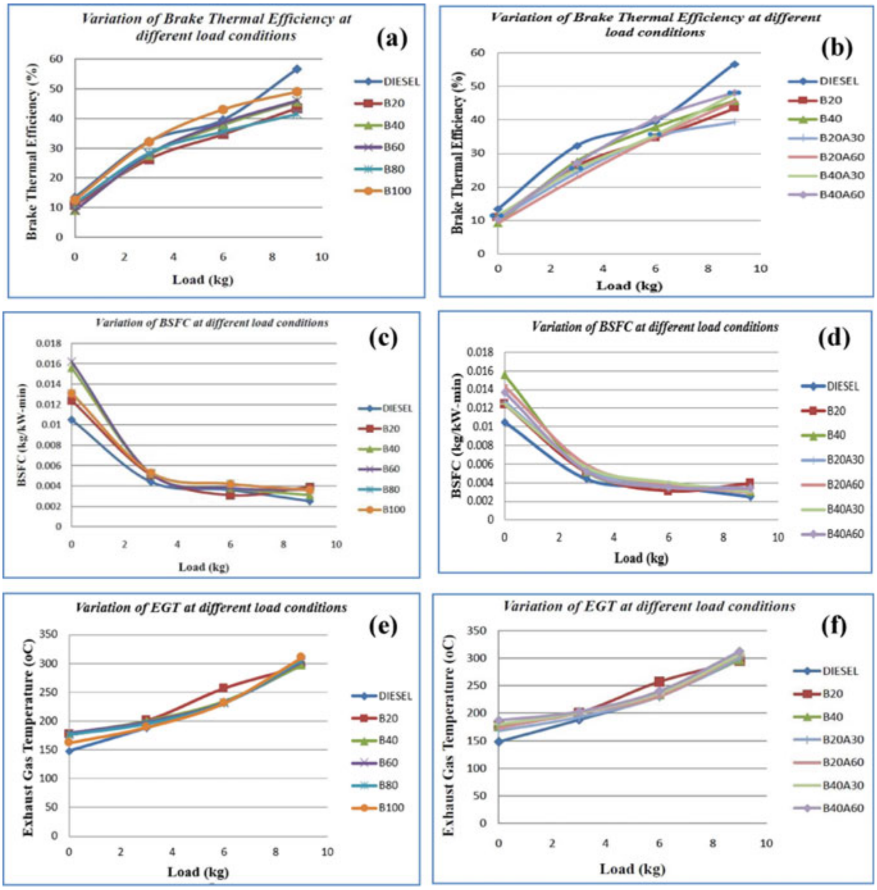

Fig. 5 **a**–**f** Variations in performance characteristics; **a** BTE without Al_2O_3, **b** BTE with Al_2O_3, **c** BSFC with Al_2O_3, **d** BSFC without Al_2O_3, **e** EGT without Al_2O_3 and **f** EGT with Al_2O_3

Exhaust gas temperature (EGT) of a fuel depends on properties like kinematic viscosity, calorific value and cetane number. It can be observed that, with an increase in load EGT also increases since more fuel is injected to maintain same power output. As biodiesel percentage increases in the blends, EGT also increases compared to diesel fuel. It is because biodiesel has more viscosity than diesel which results in poor atomization, because of which proper mixing of fuel and air couldn't happen and hence incomplete combustion occurs during combustion process hence increase in EGT. It can also be observed that addition of Al_2O_3 to blends increases the EGT compared to diesel. This is could be due to lower cetane number leads tp longer ignition delay which again causes incomplete combustion of fuel during combustion process and Increases the EGT. Highest EGT of 312 °C was observed for the blend B40A60 at high load condition.

4 Conclusions

- The cotton seed biodiesel production is not costly and it uses simple and basic system. Response surface methodology was found good and easy procedure in finding the parameters to expand the biodiesel yield.
- B20 fuel usage shown brake thermal efficiency of 43.83% and when Al_2O_3 was added into blends and compared with B20 and B40 fuel, there was BTE 45.43% in B20A60 and BTE 48.18% in B40A30.
- When diesel and biodiesel blends used for diesel engine, an increase of load showed reduction of brake specific fuel consumption. B40 blend usage resulted in 0.0031 kg/kW-min BSFC at extreme load and it is having lower BSFC next to neat diesel fuel which is 0.0025 kg/kW-min. When Al_2O_3 was added into blends and compared with B20 and B40 fuel, there was BSFC 0.0029 kg/kW-min in B20A60 and 0.003 kg/kW-min B40A30.

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