Biodiesel from Seeds of Jatropha Found in Assam, India

Pranab K. Barua
Department of Energy
Tezpur University
Assam, India
pranab_kb03@yahoo.com

Abstract

Biodiesel produced from Jatropha seeds found in Assam, India is comparable with the geodiesel marketed by the Numaligarh Refinery, Assam. Experiments have shown the superiority of Jatropha biodiesel over conventional diesel as far as sulphur content is concerned. Our biodiesel B-100 is of slightly higher density, of slightly lower cetane number, and of slightly lower final boiling point. In addition, it is of low pour point and significantly high flash point. The carbon residue is slightly higher than that of geodiesel. These points lead us to conclude that biodiesel produced from Jatropha seeds found in Assam is of good quality.

Keywords: *Jatropha curcas, biodiesel.*

1. Introduction

Since the last decade of the last century, biodiesel or methyl esters have become more attractive because of its environmental benefits and the fact that it is made from renewable resources. In a review article, Pinto *et. al.* [1] analyzed the importance of biodiesel production based on scientific articles and patents. Of the total number of species with oil producing seeds, 63 belonging to 30 plant families hold promise for biodiesel production [2]. Rapeseed-oil-methyl ester was the first type of biodiesel fuel produced commercially [3], characterized as a single feedstock of then questionable quality [4]. Recent developments have made biodiesel economically interesting in view of the research potential and the possibility of improving environmental performance, along with employment generation and empowerment of rural economy [5]. Senthil Kumar *et. al.* [6] made a comparative study of the different methods to improve the engine performance using Jatropha oil as the primary fuel in a compression ignition engine. Raw Jatropha oil resulted in slightly reduced thermal efficiency, higher smoke emissions and increased hydrocarbon and carbon monoxide emissions.

The objectives of our study were to determine the properties of Jatropha curcas seed oil, to produce biodiesel from the seed oils by transesterification using suitable process and to determine the fuel characteristics of the biodiesels produced, and to prepare various blends of each of the biodiesels with a typical petroleum diesel and determine their fuel characteristics so as to select the most suitable blends which may be used as fuels for diesel engine.

The major challenges of biodiesel are its cost and limited availability of fats and oil resources. The cost of raw materials accounts for 60 to 75% of the total cost of biodiesel fuel [7]. Moreover with the increase of human population, more land may be needed to produce food for human consumption rather than to produce oilseeds for biodiesel production.

In India where fossil fuel resources are very limited, the production and use of biodiesel from vegetable oils and fats may be a feasible solution for supplementing the ever growing demand of diesel in the country. However while selecting the sources of triglycerides for biodiesel production, special attention must be given to utilize the indigenous non-edible oils. In the forests of India, of the North East in particular, a large variety of oilseeds bearing trees and shrub species grow well in their natural habitats. The seeds of some of such trees are not normally used for any purpose, productive or otherwise. While searching for oilseed bearing indigenous trees and shrub species, we were attracted by a promising tree species of North-East India, viz. *Jatropha curcas*, which produces very significant amounts of oil seeds per plant.

With a view to utilizing the seeds, we have made an attempt to convert the seed oils to biodiesel and to examine the feasibility of using them as fuels for diesel engine. This study may be helpful in evaluating the feasibility of using locally available Jatropha seeds as a source of biodiesel that can be used in neat form or in blends in some optimum proportion. We hypothesize that if not the neat form, some particular blend may actually be good enough for commercial use. A detailed literature survey is available in a monograph by Barua [8].

2. About Jatropha curcas

Among the many species, which yield as a source of energy in the form of biodiesel, Jatropha curcas has been identified as the most suitable oil seed bearing plant due to its various favorable attributes like hardy nature, short gestation period, adaptability in wide range agro-climatic conditions, high oil recovery and quality of oil, etc. It can be planted on degraded lands through Joint Forest Management (JFM), farmer's field boundaries, road sides, both sides of the railway tracks, fallow lands and as agro-forestry crop. It grows up to a height of 5 metres and can be maintained to a desired height and shape by trimming and pruning. The Planning Commission, Government of India has identified two species for mass production of seeds for biodiesel viz. Jatropha and Pongamia. Jatropha is suitable for upland while Pongamia is found adaptive for both uplands as well as wet land conditions.

Jatropha as a plantation crop offers the following advantages. It is easy to establish; it grows quickly, and require little care. It can grow in poor soils, in wastelands except flood prone and waterlogged areas. Reclamation of wasteland and degraded land is possible through its plantation. In fertile land, it gives higher yields. Plantation of Jatropha, oil extraction and nursery raising can be rural based. Hence, it promotes rural economy besides ensuring energy security. It is suitable for preventing soil erosion including Jhum fallows. Jatropha is not a competitor of any crop. Rather, it increases the yield. Due to mycorrhizal value in Jatropha roots, it helps in getting phosphate from soil – a blessing for acid soil. It improves the soil fertility throughout their life cycle. It possesses medicinal as well as other multiple uses.

In India, Jatropha curcas is found in almost all the states and is generally grown, as a live fence for protection of agricultural fields from damage by livestock as cattle or goats do not eat it since it is non-edible. It is a tropical species and can be grown well in subtropical conditions. It grows almost everywhere, even on gravely, sandy, acidic and alkaline soils. It can thrive in the poorest stony soils. It grows even in the cracks and crevices of rocks on all types of soil except one subjected to water inundation. It does not thrive in wetland condition. If the rising water table engulf the major root system and continues for a considerable period, the plant will die. The plant is undemanding in soil type and does not even require tillage. In Assam in particular, this plant grows in the marshlands and riversides naturally. We would like to stress here that we are not really advocating for cultivation of the plant. We are rather interested to study the properties of biodiesel that can be produced from the naturally available Jatropha plants in Assam.

There is no recommended variety for this region yet. However, the variety grown in NE India is also found productive. The female: male ratio of flower which is one of the indicatives of productivity is observed to be 1:12 compared to 1:16 to 1:20 found in other states. Fruit setting in NE region is nearly 90-95%.The occurrence of fungal diseases due to high humidity and high soil moisture, the newly introduced materials from drier belts is difficult to establish. Therefore, plantation if necessary can be started with locally available one.

Jatropha can easily be propagated on mass scale both by seed as well as stem cuttings. Hot and humid weather is preferred for good germination of seed. Seeds or cuttings can be directly planted in the main field. But pre-rooted cuttings in poly bags and then transplanted in the main field give better results. For one-acre plantation, about 2-2.5 kg seeds are required. Fruiting starts from the 2nd year if propagated by stem cutting but it takes one year more while raised by seed.

Figure 1. The Jatropha Plant

The land should be ploughed once or twice depending upon the nature of soil. In direct planting system, the seed / cuttings should be planted in the main field with the onset of monsoon at a spacing of 3m*2m. In hilly areas where ploughing is not possible, after clearing jungles, pits of size 30cm*30cm*30cm is dug at required spacing, refilled with top soil and organic manures and then planted.

Two to three weedings are necessary; it does not require supplementary irrigation if planted in the onset of rain. Jatropha is deciduous in nature and the fallen leaves during winter months form mulch around the base of the plant. The organic matter from the fallen leaves enhances earthworm activity in the soil around the root zone of the plants, which improves the fertility of the soil.

Light harrowing is beneficial during early growth stage. Pinching the terminal is essential at the age of six months to induce laterals. Application of GA 100-PPM spray induces flowering and pod development.

To give a bushy shape, the plant should be trimmed during spring (Feb-March) upto 5 years including one pruning when the plants attain 1.5 m height. Thereafter, the plant should be pruned back above ground level once in 10 years at 45 cm above the ground.

At the time of planting, compost at 2kg/pit should be applied. Afterwards, depending on soil type, manuring at 3-5 kg/plant along with and NPK should be applied near the crown following ring method before monsoon.

In general, application of super phosphate at 60 kg/acre and alternate with one dose of 16:40:16 kg/acre NPK 6 monthly intervals improves yield. From the 4th year onwards, 105 extra super phosphates should be added to the above dose.

Some shade loving crops like Rouvolfia sepentina, Asparagus racemosus, Kaempferia galangal, Homalomena aromatica and Smilax china etc. and also short duration pulses and vegetables can be profitably grown under Jatropha. Vanilla can also be cultivated under it successfully.

Collar rot may be a problem in the beginning that can be controlled with 0.2% COC. The flowering is induced in rainy season and bears fruits and matures in winter. Pods are collected when they turn yellowish and after drying, seeds are separated mechanically or manually. The seeds are dried for 4-5 days to reduce moisture level 10% before packing.

The economic life of Jatropha is 35-40 years. The plant survives upto 50 years if root zone does not come in contact with rising water table and continues for longer time.

Although the fruiting stars from the 2nd year, commercial harvest is obtained from the 3rd year only. Flowering is less and delayed when grown in shady conditions. In sunny conditions, flowering is more and early (July-September). There will be about 670 plants / acre at 3m*2m spacing. Grown-up jatropha from the 6th year onwards yield 4-6 kg per plant under good management.

Higher productivity and profitability can be achieved by pruning main stem upon 1.5 m growth for profuse branching and higher seed yield, foliar spraying with growth promoters for higher yield of seeds and oil, and ensuring maximum exposure to sunlight for enhancing seed yield.

Jatropha plantation should not be taken as highly profitable cash crop if the value of by-products and other advantages are not considered. Besides, raising of intercrops along with oil, other potentially high value products such as glycerin and seed cake to make it more attractive should be effectively marketed and the environmental and socio-economic returns such as wasteland reclamation need to be adequately accounted for [9].

3. The Present Work

We are now going to describe how we extracted biodiesel from Jatropha curcas. About 10 kg of Jatropha seeds were collected from the vicinity of the Tezpur University Campus and dried at 80^0 C for 5 hours in a hot air oven. The dried seeds were shelled and milled. The oil was extracted from the milled kernels with petroleum ether (40-60^0 C) using the Soxhlet extraction method [10]. The solvent was removed from the extract and the oil content was found to be 53% by weight of the milled kernel. About 4 litres of the oil were extracted and kept over anhydrous sodium sulphate for three days and filtered through glass wool to remove the particulate matter present in it. The filtered oil was then stored in glass bottles for further experiments. Although we have collected Jatropha seeds near the Tezpur University Campus, it is the same variety available naturally in the North East ([9], pp – 122).

We now give a short description of the tests and definitions of the associated parameters. We shall follow the usual guidelines followed in such tests as was done by Sarma *et. al.* [11] and Sarma and Konwer [12]. We start with acidity first. This parameter has three facets:

a. **Total acidity:** It is a measure of the combined organic and inorganic acidity.
b. **Inorganic acidity:** It is a measure of the mineral acid present.
c. **Organic acidity:** It is obtained by deducting the inorganic acidity from the total acidity.

For determining total acidity, the sample is extracted with neutral alcohol and is then titrated with 0.1 N alcoholic potash. The inorganic acidity is determined by extracting the sample with warm water and titrating the extract with 0.1 N alkali. **Acidity** is an indication of the corrosive properties of the products.

Gross Calorific value is defined as the heat released in calories per gram or BTU per pound at 25^0 C by the combustion of a unit mass of fuel in a constant volume bomb with substantially all of the water condensed to the liquid state. It can be calculated using the following formula:

Gross calorific value (Q) = $12400 – 2100 * d^{2,}$

where d = sp. Gr. at 60^0 C. The **Gross Calorific value** thus gives a measure of the heat producing of the fuel.

Cetane Number is the most important parameter in our case. The cetane number of a diesel fuel is the percentage by volume of normal cetane in a blend with hepta methyl nonane that matches the ignition quality of the fuel when compared by this method. This is usually expressed as a rounded whole number.

The **cetane number** of a fuel reflects its ignition delay. The higher the cetane number, the shorter the ignition delays. Therefore, high cetane number is desirable for engine fuel. Cetane numbers of biodiesels differ depending on the respective oil sources. Cetane numbers of biodiesel from soybean oil methyl esters lie between 45.8 and 56.9, and that from rapeseed oil methyl esters lie between 48 and 61.8. Cetane increases with chain length, decreases with the number of double bonds, and decreases as double bonds and carbonyl groups move towards the centre of the chain. Increasing cetane number of biodiesel has been shown to reduce nitrogen oxides emissions [13].

The cetane number is determined in a single cylinder CFR engine by comparing its ignition quality with that of reference blends of known cetane number. The reference fuels used for this purpose are normal cetane (100 C.N.) and heptamethyl nonane which has a cetane number of 15. This is done by varying the compression ratio for the sample and each reference fuel to obtain a fixed ‘delay period’ that is the time interval between the start of injection and ignition.

Cetane number signifies the ignition quality of a fuel. High cetane number fuel will facilitate easy starting of compression ignition engines and lessen engine roughness. In the absence of an engine, the cetane number can be roughly assessed by the formula:

C.N. = 0.72 diesel index + 10

Figure 2. Dry Jatropha fruits

Figure 3. Jatropha seeds

Figure 4. Jatropha kernels

The above formula will not hold good when ignition improvers are added to the diesel fuel. In such cases, the engine testing will only give the true ignition quality of the fuel.

Copper Corrosion is another parameter we have tested. A cleaned and smoothly polished copper strip is immersed in the sample which is then maintained at the specified temperature for the specified length of time. This strip is removed from the sample, washed with aromatic free petroleum spirit and diethyl ether and examined for evidence of etching, pitting or discoloration. It is then compared with the ASTM copper strip corrosion standard. The **Copper Corrosion** test serves as a measure of possible difficulties with copper, brass or bronze parts of the fuel system.

Carbon Residue gives a measure of the carbon depositing tendencies of a fuel oil when heated in a bulb under prescribed conditions. While not directly correlating with engine deposits, this property is considered as an approximation. Carbon residue can be defined as the amount of carbon residue left after evaporation and pyrolysis of an oil and can to provide some indication of relative coke-forming properties. This can be determined by **Ramsbottom method**.

In the **Ramsbottom method**, the sample after being weighed into a special glass bulb having a capillary opening is placed in a metal furnace maintained at 550^o C. The sample is thus quickly heated to the point at which all volatile is evaporated out of the bulb with or without decomposition while the heavier residue remaining in the bulb undergoes cracking and coking reactions. After a specified 20 minute heating period, the bulb is removed from the bath, cooled in a desiccator and again weighed. The residue remaining is calculated as a percentage of the original sample and reported as Ramsbottom carbon residue.

Carbon Residue gives an indication of the coke forming tendency of the fuel. The Board of Revenue utilizes this property for classification of fuels for excise duty purposes. It is also used in design calculations of cockers.

Density is another parameter we have considered. The density of a gaseous substance is defined as the mass of the substance occupying unit volume at a stated temperature and a stated pressure. When reporting the density of a gas, the units of mass and volume used and the temperature and pressure of the determination must all be explicitly stated, i.e. grams per litre at t^o C and p mm pressure. Density does not have any special significance except that it is used for calculating the mass when volume of the bulk is known. **Specific gravity** of biodiesel lies between 0.86 and 0.90. Therefore volumetrically, biodiesel delivers a slightly greater amount of fuel [14].

The **ASTM Distillation Test** provides a measure in terms of volatility of the relative proportions of all the hydrocarbon components of a product. 100 ml of the sample is distilled in a distillation flask under prescribed conditions. Systematic observations of temperatures against volume of recovery are made and from these data, results are calculated and reported. Biofuels have a narrow **boiling point** range in comparison with petroleum diesel. On an average, their boiling points range from 325^0 C and 350^0 C approximately [15].

The following are certain pertinent definitions in this context.

i. **Initial boiling point:** The temperature reading observed at the instant the first drop of condensate falls from the lower end of the condenser tube.
ii. **End point or final boiling point:** The maximum thermometer reading attained during the test which usually occurs after the evaporation of all liquid from the bottom of the flask.
iii. **Dry point:** The thermometer reading which is observed at the instant the last drop of liquid evaporates from the lowest point in the flask. Any drops of film

of liquid on the side of the flask or on the thermometer are disregarded. Dry points are normally noted for solvent and light naphtha.

Significance of the ASTM distillation test varies from product to product. In case of crude oil, the ASTM distillation data gives some idea of the fractions that could be collected below 300^{o} C. If it is a true boiling point distillation (TBP), the TBP curve reveals a lot of characteristics that are the basis for the design of a refinery.

The 10% v distillation for motor spirit is an indication of the ease with which the engine can be started. It should be high enough to produce enough light ends for easy staring under normal temperature conditions but not so high that vapor lock may be experienced. Good warm up and acceleration properties can be assured by specifying in addition, a suitable maximum limit for the 50% evaporated temperature. The 90% evaporated temperature should be low enough to preclude excessive dilution of the crank case lubricating oil.

Flash point is the lowest temperature at which application of the test flame causes the vapor and air mixture above the sample to ignite. We have evaluated this parameter too. **Flash point** specifies the temperature to which a fuel needs to be heated for the vapour and air above the fuel could be ignited. The flash points of the biodiesels are generally higher than that of geodiesel. It is higher than 90^{0} C, and is thus safer than diesel from the standpoint of fire-hazards [14].

Lubricity is a measure of the fuel's ability to provide adequate lubrication of the components of the fuel system, including fuel injectors and pumps. The precision required in the manufacturing of these components and the significant influence of abnormal wear require that they be adequately protected from scuffing, wearing, scratching, etc. that may affect their fuel delivery characteristics. The level specified is consistent with that recommended by suppliers of fuel injection equipment for modern diesel engines.

Pour point is another important property of fuels for winter use in particular. Biodiesels exhibit poor flow properties at low temperature. The pour point ranges between 20^{0} and 25^{0} C, much higher than those of geodiesel. The structural properties of biodiesel that affect freezing point are degree of unsaturation, chain length and degree of branching. Pour point measures the lowest temperature at which the oil is observed to flow. It is important because this defines the lowest temperature at which the fuel can still be moved, before it has gelled. Fuels with high pour points are more difficult to use in areas with lower temperatures because the fuel must be kept warm by some method e.g. electric heaters with insulated tanks. All the biodiesels have significantly higher pour points compared to diesel; over 20% higher or more. The animal and yellow grease feedstock resulted in significantly higher values due to the higher proportions of saturated fatty acids.

Another important parameter in this context is the **Sulphur Content** in the biodiesel. This can be evaluated using energy dispersive **X-ray Fluorescence Spectrometry** (XRF). This testing method covers the measurement of sulphur in naphtha, kerosene, diesel, fuel oils, lube base oils and crude oils. The applicable concentration range is 0.015 to 5.00 mass % sulphur and time taken for testing is 5 minutes per sample. The conventional lamp or bomb method usually takes 8 hours.

The sample is placed in the beam emitted from an X-ray source. The resultant excited characteristic X-radiation is measured and the accumulated count is compared with counts from previously prepared calibration samples.

To protect the environment from sulfur dioxide emission, the sulfur content in diesel, petrol, etc. are restricted to certain maximum value. Also, in processing the hydrocarbon, different types of catalysts are used, some of which are poisoned by sulfur. Sulfur creates corrosion problems and hence its tolerance is limited.

The **Viscosity Index** is an empirical number indicating the effect of change of temperature on the viscosity of the oil. A low viscosity index signifies relatively large change of viscosity with temperature. The maximum **viscosity** of diesel should be 4.1 units at 40^0 C. Viscosity of esters of rapeseed oil exceed this significantly. The higher the viscosity, the poorer the atomization of the fuel. Accordingly, operation of the injectors would be less accurate. Moreover, at decreasing temperature, viscosity of biodiesel increases [14].

Water Content in the biodiesel is one of the important parameters to be decided. Water present in biodiesel fuels can lead to rust. Water acts also as a necessary ingredient towards microbial growth. The fuel should be clear in appearance and free of water and sediment. The presence of these materials generally indicates poor handling practices. Water and sediment can shorten filter life or plug fuel filters, which can lead to engine fuel starvation. In addition, water can promote fuel corrosion and microbial growth. The level of water specified is within the solubility level of water in fuel and, as such, does not represent free water. Limits are established to allow measured results to be compared to a maximum level acceptable for proper engine operation. The descriptions regarding the aforementioned parameters and their significances have been excerpted from the Haldia Refinery Manuals available in the Quality Control Laboratory of the Guwahati Refinery.

4. Production of Biodiesel from Jatropha Oil

The production of biodiesel (methyl ester) of *Jatropha curcas* seed oil was carried out in a 2 lit. capacity glass vessel equipped with a mechanical stirrer, a funnel and a condenser placed in water bath having a proportional integral derivative temperature control device. *Jatropha curcas* seed oil and methanol (98% pure) were mixed (6:1 molar ratio) and the mixture was placed inside the reactor, in batches. The temperature of the reactor was raised to 70^0 C, and the mixer was stirred at 600 rpm. When the mixture temperature reached 70^0 C, 4.5 g of freshly prepared sodium methoxide was added to it. Thus the reaction was continued for 1h, an optimum reaction time, as determined from three sets of experiments conducted initially for 0.5, 1, and 1.5 h duration. As soon as the reaction time was over, the mixture was placed in a separating funnel and allowed to cool for 2hours. Two distinct layers were found to form, the upper layer being the mixture of methyl ester and unreacted methanol and the lower layer was a mixture of glycerol and water. A rotary vacuum evaporator was used to recover the unreacted alcohol from the ester layer. The unreacted alcohol recovered was found to be 30ml. The ester was then washed twice with distilled water. The emulsified water was removed through rotary vacuum evaporator method. Biodiesel and glycerol were recovered by this method.

5. Properties of the Biodiesel Studied

To be able to analyze whether or not the biodiesel produced from *Jatropha curcas* seeds is efficient, it is essential to perform certain tests on them that are otherwise applied to the conventional liquid fossil fuels as well. Indeed, we are interested to compare the two kinds of fuel, biodiesel produced from Jatropha seeds found naturally in Assam, and geodiesel. In our work, it was thus chosen to prepare blends from *Jatropha curcas* seed oil and petroleum diesel produced at the Numaligarh Refinery Limited, Assam, India. Our objective was to study the properties of the biodiesel blends, and then compare the test results with those of the diesel produced by the aforementioned refinery, the properties of which were already known.

Two different blends of biodiesel from Jatropha curcas seed oil with petroleum diesel were prepared in the following compositions.

a. B-5: 5% (vol.) biodiesel + 95% (vol.) geodiesel.
b. B-10: 10% (vol.) biodiesel + 90% (vol.) geodiesel.

The petroleum diesel used in our case for blending with the biodiesel was obtained from Numaligarh Refinery Limited, Assam. In addition, we also tested for B-100 in which there was no geodiesel at all, forming entirely of biodiesel. Various properties of the biodiesel samples thus obtained from Jatropha curcas vegetable oil were determined by different standard test methods. Density was determined by ASTM D 287 method. Moisture content was determined by ASTM D 2709 method. Ramsbottom carbon residue was determined by ASTM D 4530 method. Pour point was determined by ASTM D 97 method. Flash point was determined by ASTM D 93 method. Kinematic Viscosity at 400 C was determined by ASTM D 445 method. Cetane number was determined by ASTM 613 method (in CFR cetane). Acid value was determined by ASTM D 664 method. Sulphur content was determined by ASTM D 5453 method. Initial boiling point (IBP) and final boiling point (FBP) were determined by Sim-Dis GC distillation (ASTM D 2887 and D86 correlation). Sulphur content was determined by ASTM D 5453 method. Gross calorific value was determined using the values of the densities of the samples obtained by ASTM D287 method. Copper corrosion was determined by ASTM D 130 method.

The tests to find out the characteristics of the Jatropha vegetable oil were all carried out in the Guwahati Refinery. The tests were all carried out in triplicate and average values are presented in Table 1 below.

Table 1. Jatropha vegetable oil characteristics

Properties	Values
Moisture % weight	0.0326
Ramsbottom Carbon Residue	0.22
Viscosity (cSt)	34.5
Sulfur Content %	0.0094
Gross Calorific Value (kJ/g)	46.024
Acidity	2.19
Density (kg / m^3)	935.0

The tests to find out the characteristics of the *Jatropha* vegetable oil were all carried out in the Guwahati Refinery. The tests were all carried out in triplicate and average values are presented in Table 2 below.

Table 2. Jatropha biodiesel characteristics

Properties	**B5**	**B10**	**B100**
Moisture % weight	0.0441	0.079	0.2765
Cetane Number	45.8	45.6	43.3
Ramsbottom Carbon Residue	0.08	0.12	0.39
Flash Point (^oC)	51	52	100
Pour Point (^oC)	0	3	-3
Viscosity (cSt)	3.43	3.61	9.02
Corrosive Corrosion	1a	1a	1a
Sulfur Content %	0.0929	0.0887	0.0170
Gross Calorific Value (kJ/g)	45.434	45.409	44.844
Acidity	0.48	0.66	0.75
Initial Boiling Point/Final Boiling Point ^oC	141/372	142/373	290/350
Density ($kg/m^{3)}$	855.2	858.2	898.1
Lubricity (mm)	174	176	185

The following table shows the characteristics of petroleum diesel taken from the Numaligarh Refinery. While preparing the samples of B-5 and B-10 blends of the *Jatropha* biodiesel, we have used petroleum diesel collected from the Numaligarh Refinery. Hence, for the purpose of comparison one may consult table 3 below.

Table 3. Fuel characteristics of a typical petroleum diesel obtained from Numaligarh Refinery Ltd

Property	
Density at 15^0C g/cm^3	0.852
Kinematic viscosity at 40^0 C cSt	2.781
Water content % vol	0.055
Ramsbottom carbon residue %wt.	0.10
Pour Point ^0C	0
Flash point ^0C	49
Cetane number	46
Sulphur content %wt.	0.0165
Ash content %wt.	0.010
Acid value mg KOH/g	0.104
Oxidation stability g/100ml	0.01
Copper strip corrosion	1a
Calorific value(gross) kJ/g	45.013
IBP/FBP ^0C	139/370

6. Summary and Conclusions

If even a B-5 blend of biodiesel becomes feasible economically, it would mean saving millions of rupees, and for a developing country like ours, it is precisely the reason why studies on biodiesel are of utmost importance. A vast reservoir of information on all aspects of biodiesel is available. This includes various feedstock, their characteristics, production processes & plant designs as well as performance of biodiesel in small and high horse power direct injection and turbocharged engines. It is universally accepted now that biodiesel is a renewable and biodegradable alternative fuel suitable for CI engines. It reduces the CO, HC and particulate emissions but marginally increases the NO_x emissions which can be lowered by retarding fuel injection timing and/or by using suitable additives (DTBP). The specific fuel consumption of biodiesel is slightly higher as compared to petrodiesel due to its lower heating value & higher density. Brake horsepower & torque are slightly less. In different countries, different blends and neat biodiesel is in use. Quality standards of biodiesel are now available. B5 is used in France, B20 & B100 in the USA and B100 in Austria & Germany. In other countries, environmentally sensitive areas such as schools, hospitals, towns, etc. have been targeted first for adoption of biodiesel. In many states, local tax exemptions and incentives are available for use of biodiesel.

Higher cost of biodiesel is at present the major handicap but considering ever increasing environmental pollution by the use of petrodiesel, use of biodiesel needs to be encouraged. Through research, adoption of better feedstock, higher productivity & better technology cost is bound to get reduced to attain parity with petrodiesel. In view of the ever-increasing consumption of petrodiesel (nearly 50 m-tones/year in India) and environmental concerns as well as urgency to adopt EU & Bharat norms especially in metropolitan and larger cities [16], it is high time to make all out efforts to produce & use B2 & B5 biodiesels in India. The country has about 130 m-ha of degraded and wastelands. At least, 20 m-ha out of it needs to be utilized for production of biodiesel. Currently, the most promising feedstock are Jatropha, Pongamia, Mahuva, neem, etc. However, in future, other feedstock including waste frying oil as well as food grade oils need to be exploited at least for emergency usage in agriculture. The country ought to provide incentive & price support to the farmers to increase productivity of cultivated oil seeds and use these crops for diversification of agriculture in such areas as Punjab & Haryana. The dream of ushering in the second green revolution can be realized only when adequate quantum of energy for production and post production is available on the farm.

We have in our experiments, found that the biodiesel that we produced from Jatropha seeds is comparable with the geodiesel marketed by the Numaligarh Refinery. Our biodiesel B-100 is of slightly higher density, of slightly lower cetane number, and of slightly lower final boiling point. It is of low sulphur content, low pour point, and significantly high flash point. It can be seen that for our B-5 and B-10 samples, sulphur contents are too high, whereas in B-100 it is too low. This shows the superiority of Jatropha biodiesel over conventional diesel as far as sulphur content is concerned. The carbon residue is slightly higher than that of geodiesel. Although moisture content has been found to be high in B-100, it is more or less similar in the cases of B-5 and B-10. All these points are sufficient to conclude that our biodiesel is of good quality. Therefore we conclude that the biodiesel produced from *Jatropha curcas* seeds found in Assam, India, is of a quality that can be declared good enough.

Acknowledgements

This article has been dedicated in reverential memory of Professor Dolon Konwer of Tezpur University, India, without whose help this work could not have been completed.

References

[1] Angelo C. Pinto, Lillian L. N. Guarieiro, Michelle J. C. Rezende, Nubia M. Ribiero, Ednildo A. Torres, Wilson A. Lopes, Pedro A. de P. Pereira and Jailson B. de Andrade, Biodiesel: An Overview, J. Braz. Chem. Soc., Vol. 16, No. 6B, 2005, 1313 – 1330.

[2] D. M. Hegde, Tree Oilseeds for Effective Utilization of Wastelands, in Lecture Notes, Winter School on Wasteland Development in Rainfed Area, Central Research Institute for Dryland Agriculture, Hyderabad, 2003, 111 – 119.

[3] W. Korbitz, New trends in Developing Biodiesel Worldwide, Evaluating & Exploring the Commercial Uses of Ethanol, Fuel alcohol & Biodiesel, Singapore, 22-23, April, 2002.

[4] S. R. Verma, and Ajay Sharda, Biodiesel: An Alternative Fuel for CI Engines – Global Scenario and Indian Perspective, Proceedings of the National Seminar on Biomass Based Decentralized Power Generation, Edited by B. S. Pathak and N. S. L. Srivastava, Sardar Patel Renewable Energy Research Institute, Gujarat, 2005.

[5] K. V. Raju, Biofuels in South Asia: An Overview (Editorial Introduction), Asian Biotechnology and Development Review, Vol. 8, No. 2, 2006, 1 – 9.

[6] Senthil Kumar, M., A. Ramesh, B. Nagalingam, A comparison of the different methods to improve engine performance while using jatropha oil as the primary fuel in a compression ignition engine, International conference on energy and environmental technologies for sustainable development. 8-10 Octo, 2003, 267-274.

[7] T. Krawczyk, Biodiesel- Alternative fuel makes inroads but hurdle remain. INFORM, 7, 1996, 800-815.

[8] Pranab K. Barua, Biodiesel from Seeds of Jatropha Plants Found in North East India, Lambert Academic Publishing, Saarbrucken, Germany, 2010.

[9] M. Ahmed, Cultivation of Jatropha curcas L., Aromatic – Medicinal Plants & Biodiesel, AROMA 2004, Edited by M. Ahmed and P. Deka, North Eastern Development Finance Corporation Ltd. Guwahati, Assam, 2004.

[10] H. Raheman and A. G. Phadatare, Diesel engine emissions and performance from blends of Karanja methyl ester and diesel. Biomass and Bioenergy, 27, 2004, 393-397.

[11] A. K. Sarma, D. Konwer and P. K. Bordoloi, A Comprehensive analysis of fuel properties of biodiesel from Koroch seed oil, Energy & Fuels, 19, (2), 2005, 656-657.

[12] A. K. Sarma and D. Konwer, Feasibility studies for conventional refinery distillation with a1:1 (w/w) of a biocrude blend with petroleum crude oil. Energy & Fuels, 19, (4), 2005, 1755-1758.

[13] T. Ullman, R. Mason and D. Montalvo, Study of cetane number and aromatic content effects on regulated emission from a heavy-duty engine. Southwest Research Institute Report No. 08-2940, CRC contract VE1, 1990.

[14] A. K. Sarma, Biodiesel Production from Mesua ferrea L (Nahar) and Pongamia glabra Vent (Koroch) Seed Oil, Ph. D. Thesis, Department of Energy, Tezpur University, India, 2006.

[15] M. S. Graboski and R. L. McCormick, Combustion of fat and vegetable oil derived fuels in diesel engines. Prog. Energy Combust. Sci., 24, 1998, 125-164.

[16] Agricultural Research Data Book, IASRI, ICAR, New Delhi, 2004.

Author

Pranab Kumar Barua completed his Bachelor of Technology in Mechanical Engineering from Sikkim Manipal Institute of Technology, Gangtok, India, in 2007. He completed his Master of Technology in Energy Technology from Tezpur University, India, in 2009.