A Case Study on Preparation and Characterization of Jatropha Based Biodiesel and its Blends with Waste Cooking Oil

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***Abstract*—Energy crisis due to over dependence on fossil fuels as a source of energy have shown that fossil fuels are limited finite resource and the continuous depreciation of the world oil reserves also corroborates the fact that oil is a finite non-renewable source of energy that will ultimately be exhausted. This therefore leads to the continuous agitation and research activities towards establishing alternate fuels that should be economically attractive in order to compete with currently used fossil fuels. Biodiesel production from renewable sources such as vegetable oils and animal fats offers the potential of both reducing fossil carbon emissions and producing alternative ultra clean transportation fuels. Biodiesel is commonly produced by the trans-esterification of the vegetable oils or animal fat feedstock. There are several methods for carrying out this trans-esterification reaction including the common batch process, supercritical processes, ultrasonic methods, and even microwave methods. In this present work, biodiesel (mixture of fatty acid methyl ester, FAME) was prepared from multi-feedstock of jatropha and its various blends with waste cottonseed cooking oil which was collected from college canteen of Institute of Technology, Nirma University, Ahmedabad, Gujarat, India using microwave oven technique. The characterization of biodiesel and its blends with petro-diesel were carried out using various methods as mentioned in the literature.**

Keywords – *biodiesel, petro-diesel, biodiesel blends, microwave, FAME*

I. INTRODUCTION

Energy is one of the most important resources for mankind and becomes prime concern when it comes to sustainable development. The current methods to produce, convert and consume energy derived from fossil fuels throughout the world are not sustainable because of which today the energy crisis becomes one of the global issues confronting us [1, 2]. The current shortage of oil and other fossil fuels not only challenges economic performance, but the state of the environment as well. Biomass derived fuels such as ethanol and biodiesel are well accepted alternatives to diesel fuels as they are economically feasible, renewable, environmental friendly and can be produced easily in urban areas where there is acute need for modern forms of energy [2].Today's diesel engines require a clean burning, stable fuel that performs well under the variety of operating conditions. Biodiesel is the only alternative fuel that can be used directly in any existing diesel engine [4]. Although, high viscosity of biodiesel has been reported as one of its major disadvantages as it affects fuel injector which ultimately leads to poor combustion of fuel in engine. This problem is further worsened at low temperatures [3]. Since biodiesel has similar properties to diesel fuel, it can be blended in any ratio with diesel fuel so as to improve engine efficiency. Biodiesel methyl esters are reported to be good lubricant (about 66% better than petrodiesel) and hence they reduce long term engine wear in diesel engines. Biodiesel blends are referred to as BXX. The XX indicates the amount of biodiesel in the blend (i.e., a B80 blend is 80% biodiesel and 20% petro-diesel) [5].

II. LITERATURE SURVEY

Biodiesel is a renewable clean biofuel commonly consisting of mono alkyl ester of long chain fatty acids derived from vegetable oils and animal fats, through the process of trans-esterification meeting the requirements of ASTM D675 [5].There are several methods for carrying out this trans-esterification reaction including the common batch process, supercritical processes, ultrasonic methods, and even microwave methods. A typical trans-esterification reaction can be represented in general as:

$$Triglyceride + 3(Methanol) \xrightarrow{Catalyst} Glycerin + 3Methyl\ Ester\ (Biodiesel)$$

The properties of biodiesel resemble to that of diesel fuel to a great extent; thus becoming a promising alternative to diesel fuel. It burns similarly like petro-diesel and has better efficiency than gasoline [5]. The main advantages of biodiesel over petrodiesel are listed below [6]:

a. It is a renewable biodegradable fuel that could be sustainably supplied.
b. It has minimal toxicity and is environmental friendly in terms of very low sulfur release and no net increased release of carbon dioxide, aromatic compounds or other chemical substances that are harmful to the environment.
c. It has lower combustion emission profile as it does not contribute to global warming because of its closed carbon cycle. It also provides improved combustion over petro-diesel because of its high oxygen content.
d. It can be used in existing petrodiesel engines with very little or no modifications and can provide good engine performance.
e. It can be blended with diesel in various proportions ranging from 5% to 20% so as convert fuel with poor lubricating properties into an acceptable fuel.

Although, there are several concerns regarding use of biodiesel as fuel [6]:

a. It emits higher NO_x emissions as compared to petrodiesel.
b. Its high cloud and pour point creates problems in cold weather conditions.
c. It has corrosive nature against copper and brass.
d. It has a very low volatility.

A. Feedstocks for Biodiesel

Biodiesel can be produced from a wide variety of feedstocks. The best feedstock can be selected considering various factors like the geographical location, climate, local soil condition, and agricultural practice of each country [6].

Therefore, a great economic advantage could be achieved simply by using more economical feedstock such as waste fats and oils. In general, biodiesel feedstock can be divided into four main categories [7]:

a. Virgin edible vegetable oils such as soyabean, sunflower, cottonseed oils.
b. Non-edible oils such as those derived from jatropha, karanja, tall, sea mango.
c. Waste vegetable oils.
d. Animal fats such as yellow grease, tallow, chicken fat, fish oil.

Most of the biodiesel producing countries use readily available edible oilseeds as feedstock, for example sunflower and rapeseed in Europe and soyabean in the USA. But the same approach cannot be adopted in India as the domestic consumption demand for edible oil often exceeds domestic production thus the country has to import edible oil from surplus oil producing countries. Also it can’t afford to produce more oilseeds as it simply means a shift in cropping pattern from food grains to non-food grains which ultimately leads to a typical food vs. fuel crisis causing scarcity of food grains which in turn will have adverse effect on inflation and poverty. Therefore, the option left for India is non-edible oilseeds which can be grown in wastelands [9].

Table 1: Physical properties of biodiesel [8]

Common name	Biodiesel
Common Chemical name	Fatty Acid Methyl Ester (FAME)
Chemical Formula Range	C_{14}–C_{24} methyl esters
Kinematic viscosity range (mm^2/s, at 313 K)	3.3–5.2
Density Range (kg/m^3, at 288 K)	860–894
Boiling point range (K)	>475
Flash point range (K)	420–450
Distillation range (K)	470–600
Vapor pressure (mm Hg, at 295 K)	<5
Solubility in water	Insoluble in water
Physical Appearance	Light to dark yellow, clear liquid
Odor	Light musty/soapy odor
Biodegradability	More biodegradable than petroleum Diesel
Reactivity	Stable, but avoid strong oxidizing agents

According to European Waste Catalogue, it is especially prohibited to dispose of liquid waste at any landfill. For this reason waste cooking oils must be reused. The main contributors to production of waste oil are frying shop industries, catering establishments, small restaurants and bars.

Nowadays various edible and non-edible oils are blended to give rise to a new range of feedstocks for biodiesel production often termed as multi-feedstocks for biodiesel production.

III. Scope Of Work

Biodiesel Production from blending of jatropha and waste cooking oil (WCO) is a promising alternative. Waste cooking oil and fats set forth significant disposal problems in many parts of the world. This environmentally-threatening problem could be turned into both economic and environmental benefit by proper utilization and management of waste cooking oil as a fuel substitute.

In the present work several experiments were conducted to compare the biodiesel production from multi-feedstock obtained by blending jatropha with waste cooking cottonseed oil in various proportions. The biodiesel thus obtained was then blended with the produced biodiesel with petrodiesel to produce B20 blends. The objective of this study can be achieved by the following procedure:

a. Production of biodiesel by blending edible and non-edible oil i.e. jatropha and waste cottonseed oil in various proportions by microwave assisted catalyst transesterification using KOH as catalyst.
b. Characterization of the biodiesel produced to determine the conversion, density, cloud point and pour point.
c. The next step was production of B20 biodiesel blends with petrodiesel and its characterization.

IV. Materials And Methods

It is established that the production of waste cooking oil will be the function of the frying temperature and duration of use as well as the material to be prepared by frying. For the experiments carried out, waste cooking cottonseed oil was collected from college canteen of Institute of Technology, Nirma University, Ahmedabad, Gujarat, India and jatropha was obtained from CSMCRI, Bhavnagar, Gujarat, India. To remove impurities from jatropha and waste cottonseed cooking oil was first pretreated with concentrated sulphuric acid. Other chemicals used were potassium hydroxide and methanol.

A. Trans-esterification Reactions:

First various multi-feedstocks were obtained by blending various proportions of jatropha with waste cooking oil. The microwave assisted trans-esterification reaction was then carried out keeping multi-feedstock to methanol ratio as 1:6 at room temperature and 700 rpm. The microwave irradiation power and time was kept constant at 600 Watt for 1 minute. Potassium Hydroxide (KOH) is used as a catalyst 1% by weight of oil. After the transesterification reaction biodiesel was separated from glycerol using separating funnel and finally washed with distilled water. Biodiesel prepared was then blended with petro-diesel obtained from Indian Oil petrol pump to obtain B20 blend.

B. Analysis of Biodiesel and B20 Blend:

Several properties of biodiesel and B20 blend were characterized by specific methods. Equipments used for characterization are given in Table 2.

Table 2: Equipments/Glassware used for characterization of biodiesel and B20 blend

Properties	Equipments/Glassware
Density	Specific gravity Bottle
Cloud Point and Pour Point	Cloud point and Pour point apparatus, Rasayan Make
Kinematic Viscosity	Reverse Flow Tube Viscometer

Figure 1: Cloud point and Pour point apparatus, Rasayan Make

Table 3: Characterization of biodiesel

Sample No.	Vol% (WCO)	Density (gm/ml)	Conversion	Kinematic Viscosity (mm^2/sec)	Pour Point (^oC)
BD-1	15	0.8971	84.8015	0.4203	-8.3
BD-2	25	0.8787	84.3736	0.3794	-11
BD-3	35	0.8834	83.5079	0.3718	-6.3
BD-4	50	0.8808	88.5231	0.3599	-8
BD-5	65	0.9191	81.3983	0.3929	-5.3
BD-6	75	0.8621	80.6420	0.3955	-2.4
BD-7	85	0.8673	81.9854	0.4181	-0.2
BD-8	100	0.8775	83.8263	0.4074	-13.1

Figure 2: Reverse flow tube viscometer

V. Results And Discussions

The biodiesel produced had the density in the range which was found to correspond to the value provided in Table 1. The percentage conversion obtained for various proportions of biodiesel was found to vary in range of 80-90%. It was found that highest conversion was obtained for the multi-feedstock prepared by blending equal volumes of both jatropha and WCO. The pour points of biodiesels were found to be in varying in range of 0 to -11^{0}C.The major advantage of biodiesel obtained by using multi-feedstock of jatropha and WCO was drastic suppression in the pour point without hampering the conversion rates that obtained for biodiesel production from jatropha. The depression in pour point by about 3-5^{0}C would enable the use of biodiesel in cold regions where the fuel tends to solidify due to ambient conditions. Also the transportation and handling costs of such fuel would become relatively easier in such regions. The blending of waste cooking oil with jatropha not only reduces dependency on jatropha as a feedstock for biodiesel production but also provides with a viable and profitable solution to the disposal problem of waste cooking oil. Moreover the blending of waste cooking oil with relatively costly jatropha significantly improves the economics of the whole process.

The results obtained after preparation of biodiesel and its characterization is tabulated in table 3.

A. Results of B20 blend of biodiesel blend with diesel:

The results obtained for the B20 blends of obtained biodiesel and petro-diesel were obtained as follows:
The viscosity and pour points of the blends listed in Table 4 were found to be in range of that of pure diesel. Whether the obtained biodiesel blends will be compatible with present diesel engines to deliver satisfactory engine performances is yet to be determined.

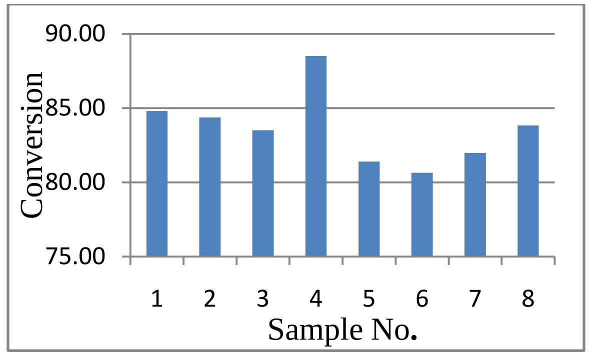

Figure 3: Conversion of biodiesel with respect to addition of waste cooking oil in jatropha

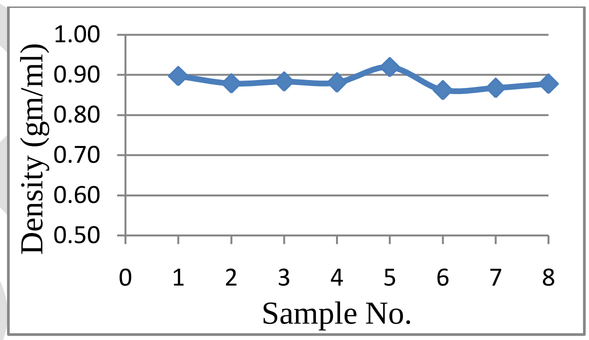

Figure 4: Density of biodiesel with respect to addition of waste cooking oil in jatropha

Table 4: Characterization of blended biodiesel

Sample No.	Vol% (WCO)	Kinematic Viscosity (mm^2/sec)	Pour Point (^{o}C)
BD-1	15	0.0632	-12.0
BD-2	25	0.1063	-15.0
BD-3	35	0.1493	-14.5
BD-4	50	0.2136	-16.0
BD-5	65	0.2778	-10.5
BD-6	75	0.3206	-14.5
BD-7	85	0.3635	-13.5
BD-8	100	0.4276	-11.0

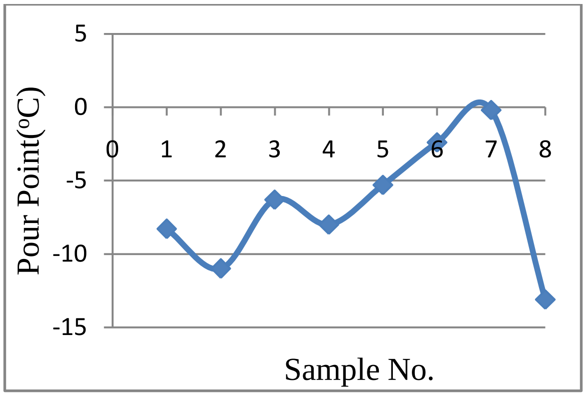

Figure 5: Pour point of biodiesel with respect to addition of waste cooking oil in jatropha

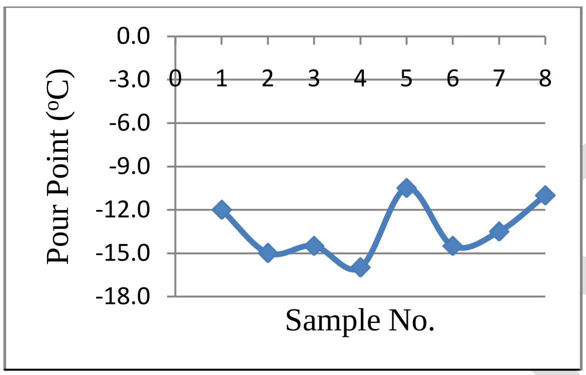

Figure 6: Pour point versus B20 blended samples

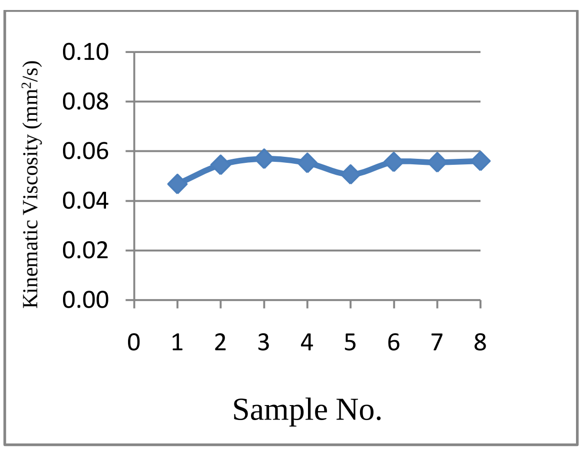

Figure 7: Kinematic viscosity versus B20 blended samples

VI.

VII. CONCLUSION

The production of biodiesel from waste cooking oil and its multi-feed stock obtained by mixing it with jatropha not only deals with the disposal problem concerned with waste cooking oil; but also provides us with a viable and profitable reuse. The still unexplored dimension of biodiesel from multi-feedstocks gives promising results as far as jatropha and waste cooking oil is concerned. Multi-feedstock production could prove to be very advantageous as it enables reduction of dependency on single feedstock; thus suppressing price volatility in order to produce high quality biodiesel economically. The cost of a more expensive feedstock can be blended with cheaper feedstock in order to maintain same profits. The diversifying feedstock will increase the process flexibility. Yet the challenge lies in ensuring the quality of biodiesel so as to meet the specifications set by ASTM D 6975. A much needed research is required in especially this sphere of biodiesel production so as to determine a more efficient productive and feasible technique for mass scale production of biodiesel.

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APPENDIX

PROCESS FLOW DIAGRAM