OPEN ACCESS

International Journal Of Modern Engineering Research (IJMER)

Production of Biodiesel from Waste Cooking Oil

Murchana Pathak[1], Nilanjana Kalita[2], Debarshi Baruah[3], Rajib Bhowmik[4]

[1,4] *Mechanical Deptt., Girijananda Chowdhury Institute of Management and Technology, Ghy, Assam, India*

[2] *Department of Mechanical Engineering, Assam Engineering College, Ghy, Assam, India*

[3] *Indian Institute of Technology, Guwahati, India*

ABSTRACT : *With the increase in crude oil prices the need for development of economically attractive alternate fuels has increased. Biodiesel from waste cooking oil is one such alternative. The project involves setting up of a laboratory scale production unit for biodiesel conversion from waste cooking oil, collected from different sources. Methanol, with sodium hydroxide as a catalyst, reacts with the waste oil in the transesterification process producing Fatty Acid Methyl Esters (FAME) with glycerine as a by-product. Properties of the FAME sample including density, viscosity, flash point, pour point, sulphur content, cetane index and calorific value are tested according to ASTM standards and compared with those of standard diesel, establishing the FAME sample as biodiesel. The project also included blending of biodiesel with standard diesel and their properties were tested and compared. The production of biodiesel from waste cooking oil offers economic and environmental solutions along with waste management. The project, thus, aims at utilizing leftover cooking oil, for a possible conversion of biodiesel.*

Keywords: *Biodiesel, FAME, transesterification, waste cooking oil.*

I. Introduction

The energy demand is majorly fulfilled from the conventional energy resources like coal, petroleum and natural gas. Petroleum based fuel are very limited reserves and only concentrated in certain regions of the world. To meet the global rising of energy demands, more reliable energy sources that are not dependent on fossil fuel are needed. In this perspective, considerable attention has been given towards the production of biodiesel as a diesel substitute as it is derived from renewable biomass sources.

Biodiesel is an oxygenated, sulphur-free, biodegradable, non-toxic and eco-friendly alternative to diesel oil [1]. It is composed of mono-alkyl esters of long chain fatty acids derived from renewable sources like vegetable oil, animal fat and used cooking oil and is designated as B100. For these to be considered as viable transportation fuels, they must meet stringent quality standards. One popular process for producing biodiesel is transesterification. Biodiesel can also be produced from virgin vegetable oils, rape seed, canola, etc. but the process is not feasible because of high cost of virgin oils. So, biodiesel produced from waste cooking oil is not only economically favourable but also environmentally beneficial as it provides a cleaner way of disposing these products. Biodiesel contains no petroleum but it can be blended with petroleum diesel in any percentage. Biodiesel blends from 2- 20% can be used in most diesel equipment with minor or no modifications [2].

II. Methodology

Equipments and apparatus required for the laboratory scale production of biodiesel:
1. Rotamantle or magnetic stirrer
2. Helical Condenser
3. Separating funnel
4. Two mouthed conical flask
5. Thermometer
6. Stand for separating funnel and helical condenser
7. Retort ring for separating funnel and helical condenser
8. Rubber tubes for supply of water
9. Weighing balance

Reagents:
1. Methanol (CH_3OH)
2. Sodium Hydroxide (NaOH)

2.1 Preparation of biodiesel from waste cooking oil (laboratory scale)

- Waste oil is collected from three different restaurants in Guwahati and named as Sample I, II and III respectively. The waste oil is filtered using a filter paper.
- A certain amount of the filtered oil is taken in a conical flask and heated in the rotamantle to melt the lumpy particles in the oil. The magnetic needle in the rotamantle helps in uniform mixing and heating of oil.
- Sodium hydroxide pellets are mixed with methanol and the solution is stirred continuously until the pellets are dissolved completely and a sodium methoxide solution is formed.
- The sodium methoxide solution is poured slowly to the heated oil and the mixture is allowed to stir and heat for two hours. The helical condenser is fitted to the conical flask to prevent the methanol from vaporizing. A thermometer is inserted through the second mouth of the conical flask to keep a check on the temperature.
- After stirring, the solution is poured into the separating funnel and is allowed to settle for 8 hours. A major part of the separation takes place in the first hour after the reaction and so a separation progress can be seen. Within 8 hours the glycerin will fall to the bottom of the separating funnel and the layer above glycerin is methyl esters which is lighter in colour than the bottom layer. The bottom layer comprises of glycerin, sodium hydroxide and methanol.
- The stopcock at the bottom of the separating funnel drains the glycerin out in a container. When the glycerin is fully drained the valve is shut.
- The glycerin left in the biodiesel sample comprises of soap which emulsifies when hot water is poured and forms a milky layer which is drained through the stopcock.

2.2 Processing of Oil in Transesterification Process

- Transesterification process is the most common way to produce biodiesel. It is a catalyzed chemical reaction involving vegetable oil and an alcohol to yield fatty acid alkyl esters and glycerol.
- Vegetable oil molecule (triacyglycerols or triglycerides) comprises of 3 esters attached to a molecule of glycerine.
- When vegetable oil reacts with an alcohol (i.e., methanol), each triglyceride molecule is broken into three fatty acid chains or esters.
- The three esters are released from the glycerol skeleton and combine with the alcohol to yield fatty acid alkyl esters (i.e., fatty acid methyl esters or FAME).
- Sodium hydroxide (NaOH) is used as a catalyst to break the triglycerides. The catalyst then combines with glycerin and falls to the bottom of the container.
- Glycerol is produced as a by-product.

The reaction involved in the production of biodiesel and glycerol are:

$$\begin{array}{ccccccc} \mathbf{CH_2\text{–}OOC\text{–}R_1} & & & & \mathbf{R_1\text{–}COO\text{–}R} & & \mathbf{CH_2\text{–}OH} \\ | & & & & | & & | \\ \mathbf{CH\text{–}OOC\text{–}R_2} & + & \mathbf{3ROH} & \underset{}{\overset{\textbf{Catalyst}}{\rightleftharpoons}} & \mathbf{R_2\text{–}COO\text{–}R} & + & \mathbf{CH\text{–}OH} \\ | & & & & | & & | \\ \mathbf{CH_2\text{–}OOC\text{–}R_3} & & & & \mathbf{R_3\text{–}COO\text{–}R} & & \mathbf{CH_2\text{–}OH} \\ & & & & & & \\ \textbf{Triglyceride} & & \textbf{Alcohol} & & \textbf{Esters} & & \textbf{Glycerol} \end{array}$$

2.2.1 Glycerol

Glycerol is the by-product of the transesterification process. It is the usual name of 1,2,3-propanetriol. Glycerol is highly viscous, odorless, transparent, colourless and has low toxicity. Glycerol is hygroscopic and has humectants properties. It is used for making soaps, explosives, cosmetics, ointments and certain inks [3].

III. Results and Discussion

Three samples of waste oil have been collected from three different units and have been named as Sample I, II & III. After processing, their properties as well as the blended samples have been tested in Numaligarh Refinery Limited (NRL), Assam.

TABLE I: Fuel properties and their measuring equipments

Sl. No.	Properties of Fuel	Measuring Equipments
1.	Density	LEMCO Hydrometer
2.	Kinematic Viscosity	STANHOPE-SETA KV-6 Viscometer bath
3.	Dynamic viscosity	Kinematic viscosity / Density
4.	Flash point	PEMI Closed Cup apparatus
5.	Pour Point	ISL PDC Automatic Pour point analyzer.
6.	Sulphur Content	Oxford Instruments MDX1000 X-ray Fluorescence (WDXRF) Automatic Analyzer
7.	Distillation	ISL ATM Distillation Analyzer AD865G2

3.1.1. Properties testing of Sample I, II & III

TABLE II: Properties Test of prepared biodiesel samples

Properties		Sample I	Sample II	Sample III
Density (gm/cc)	At 26°C	0.8810	0.8780	0.8770
	At 15°C	0.8875	0.8855	0.8846
Kinematic Viscosity (cs)		4.571	4.573	4.561
Dynamic Viscosity (cs)		5.19	5.16	5.15
Flash Point (°C)		44.5	37.0	44.0
Pour Point (°C)		-7	-7	-8
Sulphur Content (ppm)		13	72	18
Cetane Index		47.07	47.12	47.11
Calorific Value (KJ/kg)		10745.92	10753.37	10756.71

TABLE III: Distillation of the prepared Biodiesel Samples

Percentage Recovery	Temperature (°C)		
	Sample I	Sample II	Sample III
IBP	128.4	124.5	121.7
5%	197.2	188.5	185.2
10%	283.3	279.7	277.6
30%	319.2	311.5	305.1
50%	347.7	337.8	338.4
70%	351.2	345.2	343.7
90%	360.1	358.9	356.9
95%	368.4	362.2	359.2
FBP	372.1	367.6	365.9

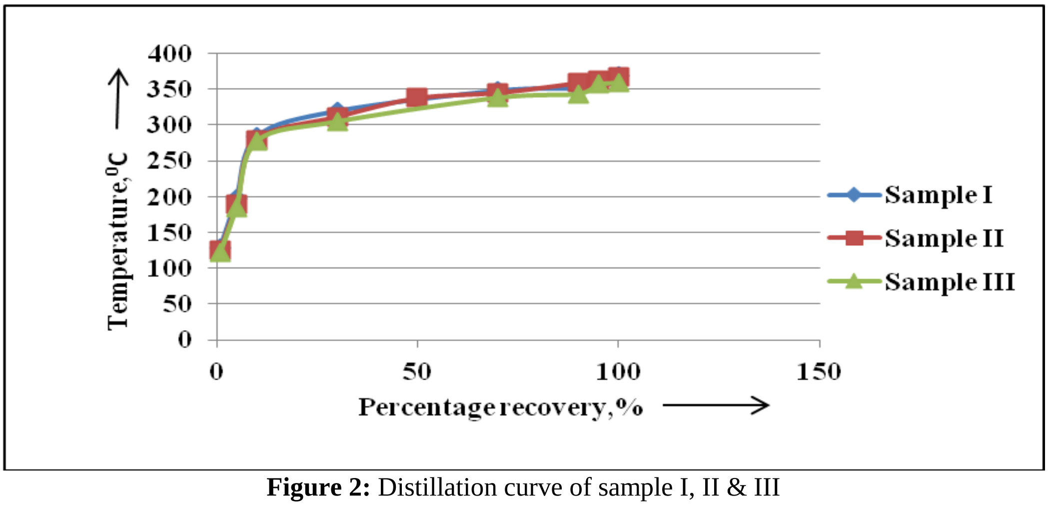

Figure 2: Distillation curve of sample I, II & III

3.1.2. Blending of Sample I & II with Intermediate Diesel Sample (105-A) from NRL

Blend 1: 90% of Sample 105-A with 10% of Sample I (B10)
Blend 2: 80% of Sample 105-A with 20% of Sample I (B20)

TABLE IV: Distillation of the Blended Samples I & II

Percentage Recovery	Temperature (°C)	
	Blend I	Blend II
IBP	132.3	138.4
5%	154.7	159.2
10%	176.3	181.2
30%	243.6	257.1
50%	277.1	291.2
70%	303.3	319.2
90%	338.9	323.7
95%	355.6	337.6
FBP	362.6	356.3

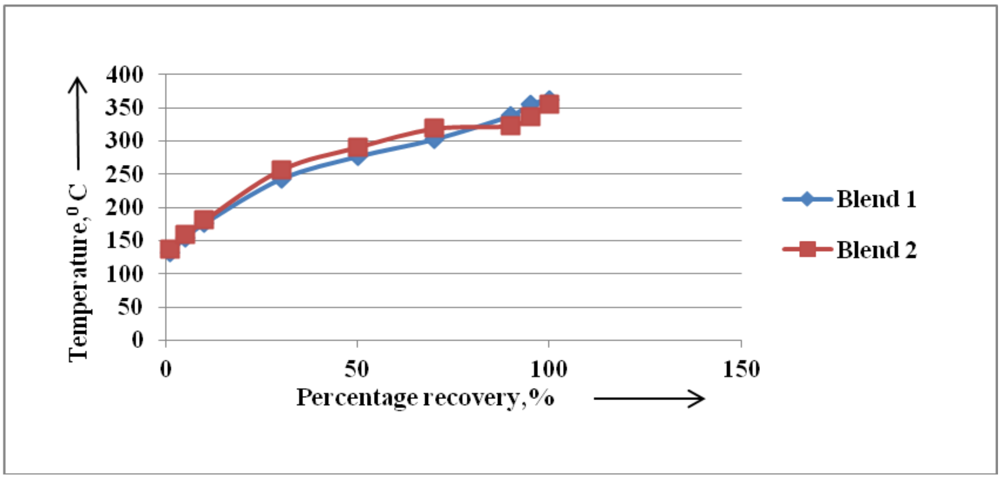

Figure 3: Distillation curve of Blend 1 and Blend 2

TABLE V: Comparison of the properties of Diesel, Biodiesel and Blended Biodiesel

Sl No.	Properties	Diesel sample	Blended Biodiesel(B10)	Blended Biodiesel(B20)	Pure Biodiesel(B100)
1	Density (gm/cc) at 15^{0}C	0.8442	0.8471	0.8521	0.8875
2	Kinematic Viscosity (cs)	2.25	2.83	3.57	4.57
3	Dynamic viscosity (cs)	2.67	3.37	4.18	5.19
4	Flash point (°C)	42	44	44	44.5
5	Pour point (°C)	-9	-12	-12	-7
6	Sulphur content (ppm)	345	363	268	13
7	Cetane index	46.9	46.95	46.51	47.07
8	Calorific value (KJ/kg)	10903.39	10893.09	10875.24	10745.92

From TABLE V, it can be seen that density and viscosity is highest in pure biodiesel followed by blended form and standard diesel in the decreasing order. Biodiesel has a higher flash point than standard diesel, thus making it less volatile and safe to transport or handle than standard diesel. The cetane index of blended biodiesel and standard diesel was found to be nearly similar but lower than that of pure biodiesel. Also, the sulphur content of biodiesel (B100) is very less compared to that of blended biodiesel and standard diesel. The calorific value is highest in standard diesel, followed by blended and pure biodiesel. From the distillation test we find that the IBP of biodiesel is less than standard diesel as biodiesel contains some amount of methyl and have a large number of small hydrocarbons but the FBP of biodiesel is higher than that of petroleum diesel.

IV. Conclusion

The used cooking oil that generally goes to waste can be utilized for producing biodiesel, which is both economically and environmentally favorable. Compared to petroleum based diesel, biodiesel has a more favorable combustion emission profile, such as low emission of carbon monoxide, particulate matter and unburned hydrocarbons. Carbon dioxide produced by combustion of biodiesel can be recycled by photosynthesis, thereby minimizing the impact of biodiesel combustion on the greenhouse effect. It provides lubricating properties that can reduce engine wear and extend engine life. In brief, these merits of biodiesel make it a good alternative to petroleum based fuel and have led to its use in many countries especially in environmentally sensitive areas [4].

Acknowledgements

The authors acknowledge the technical support of Numaligarh Refinery Limited (NRL), Assam.

REFERENCES

[1]. M. Canakci, J. Van Gerpen, 'Biodiesel Production From Oils And Fats With High Free Fatty Acids'

[2]. Haq Nawaz Bhatti, Muhammad Asif Hanif, Umar Faruq, Munir Ahmad Sheikh, 'Acid and Base Catalyzed Transesterification of Animal Fats to Biodiesel' 2008.

[3]. S. D. Romano and P. A. Sorichetti, 'Dielectric Spectroscopy in Biodiesel Production and Characterization', 2011

[4]. Y. Zhang, M.A. Dube, D.D. McLean, M. Kates, 'Biodiesel production from waste cooking oil: 1. Process design and technological assessment' 21 January 2003.