MIE10-088

Catalytic Upgrading of Vegetable Oil

*Abdullah Al-Faruk[1], Md. Abdullah Al Bari[1], Mohammed Shaheed[1], Abdullah Al Jubayer[1], and Mihir Ranjan Halder[1]**
[1] Department of Mechanical Engineering, Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH

ABSTRACT
Modern civilization is totally dependent on energy. Out of many sources of energy, fossil fuel is still the main source of energy. The present worldwide scenario of fossil fuel crisis compels the mankind to think of searching alternative fuel source. That is why people are trying to use renewable sources of energy globally. Diesel engines are used in the field of automobiles, marine, irrigation, power generation etc. Biodiesel or its blend can be used as fuel in a diesel engine. Biodiesel as an alternative of diesel can be produced from vegetable oil, which is a source of renewable energy. In the present paper, production of biodiesel from soybean oil and sesame oil, its properties and comparison of test results with the results of other biodiesels and diesel have been presented. Biodiesels are produced experimentally from soybean and sesame oils and obtained 89.75% and 82.64% respectively. Calorific values of biodiesels from soybean and sesame oil are obtained 41.57MJ/Kg and 43.67 MJ/Kg and the same for diesel is 44.5 MJ/Kg. The kinematic viscosity of biodiesel extracted from soybean and sesame oils are $2.068*10^6 m^2/s$ and $2.292*10^6 m^2/s$ respectively while the same for diesel is $2.068*10^6 m^2/s$. Again, flash point of biodiesels from soybean and sesame oil are obtained 96°C & 94°C and the same for diesel is 75°C. The production costs of biodiesels from soybean and sesame oil are Tk. 296.8 and Tk. 370 per liter respectively. These oils or any of its blend could be used as an alternative in case of crisis.

Keywords: Biodiesel, Soybean Oil, Sesame Oil, Calorific Value, Flash point

1. Introduction

Fuel is defined as a substance that can be burnt or modified by some chemical or nuclear process to produce heat energy. The non-renewable nature and limited resources of petroleum fuels has become a matter of great concern. The economic and political factors are greatly associated with their procurement. The combustion of these fuels in I.C. engines causes environmental pollution. All these aspects have drawn the attention to conserve and stretch the oil reserves by way of alternate fuel research [1]. From the seeking for alternative energy it is found that biodiesel from different plant can be the biggest source of the alternative fuel.

The exhaust emission of I.C. engine is a burning question for today. The burning of fossil fuels for centuries has polluted our environment considerably. For the emission, the percentage of CO_2, CO, NO_x, SO_2 in atmosphere has crossed safety limits. Limited energy resources and increasing emission regulations have motivated an intense search for alternative fuels over the last three decades. Alternative fuels that can be blended with existing fossil fuels have a distinct advantage because they can be used when available but the vehicle can also be fueled with conventional fuels when the alternative is unavailable [2].

In Bangladesh, diesel is primarily used for transportation, agriculture and power generation. Diesel is becoming scarce and costlier and our reservation of gas is decreasing day by day. For power generation, gas and coal should be used wherever possible to decrease the load on diesel [3]. Transportation of goods and people in Bangladesh is dominated by road transport, which accounts for 80% of all 1,50,000 motor vehicles and 49% of freight. Besides this, the rapid growth of industrialization in Bangladesh demands a much higher level of energy consumption. Thus there is urgent need to take all necessary steps for energy management and conservation.

There are several possible alternative sources of fuels. These are vegetable oils, alcohol such methanol and ethanol; hydrocarbon gases such as compressed natural gas (CNG), liquid petroleum gas (LPG), hydrogen producer gas etc [4]. Among them, vegetable oil presents a very promising alternative to diesel oil since they are renewable and is easily available in rural areas where there is an acute need for modern forms of energy [5].

Biodiesel consists of mono alkyl esters produced from renewable resources such as animal fats, waste cooking oils, yellow grease and all kinds of edible and non edible vegetable oils. In 1895, Dr. Rudolf Diesel invented the diesel engine with the intention of running it on a variety of fuels, including vegetable oil. In fact, when he demonstrated his engine at the World Exhibition in Paris in 1900, he used peanut oil as fuel. However, biodiesel and vegetable oil are very different. Raw vegetable oil or recycled greases that have not been processed into esters are not biodiesel [6]. Neat vegetable oil has high viscosity and tendency to polymerize during storage and combustion. All these lead to fuel filter clogging, ring sticking, gum formation, accumulation of oil in the lubricating system, sludge formation, poor atomization in spray system, incomplete

* Corresponding author. Tel.: +88-01714087353
E-mail address: drmrhalder@yahoo.com

combustion and injector choking [7]. Technical aspects of biodiesel are approached; such as the physical and chemical characteristics of methyl ester related to its performance in compression ignition engines. Advantages of biodiesel are as follows:

- ✓ It is renewable.
- ✓ It is biodegradable.
- ✓ It can be domestically produced which can reduce the imports of diesel.
- ✓ It is energy efficient.
- ✓ It displaces petroleum-derived diesel fuel.
- ✓ It can be used as a 20% blend in most diesel equipment with no or only minor modifications.
- ✓ It can reduce global warming gas emission.
- ✓ It can reduce tailpipe emissions, including air toxics.
- ✓ It is nontoxic and suitable for sensitive environments.

Vegetable oils are triglycerides and highly viscous. Vegetable oil can be converted into lighter molecular weight substances by cracking or transesterification. Biodiesel may be produced in several ways, but the most common technique is transesterification. In this process, glycerides in the fat or oil are reacted with an alcohol in the presence of a catalyst to produce esters and glycerin. Specifically, the oil and fat are most often reacted with methanol or ethanol in the presence of a catalyst like sodium hydroxide or potassium hydroxide to form methyl or ethyl esters and glycerin. Biodiesel when used as a pure fuel is known as B100. Biodiesel is a fuel that can be blended easily with fossil diesel fuel and offers several advantages over diesel fuel. The blend is designated "BXX" where XX is the percentage of biodiesel in the blend.

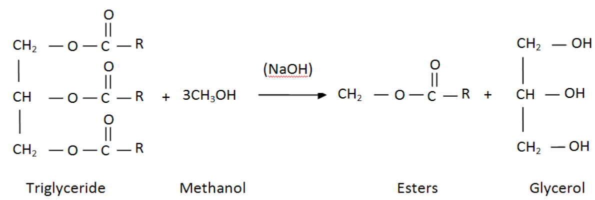
Previous studies of a few researchers including Kothe et al, the effect of biodiesel on engine performance revealed that biodiesel reduces emissions including CO, total unburnt hydrocarbon (THC), and PM except NOx [8].In the present work biodiesels are produced from soybean oil and sesame oil and the thermo-physical properties of biodiesels (B100) are studied.

2. Catalytic conversion of vegetable oil into biodiesel

Vegetable oils are carboxy-esters. The physical properties of these carboxy-esters are only moderately sensitive to the free-fatty acid they are made from, and the resulting biodiesel contains little of the free fatty acids or oxidation products which the vegetable oils are made from. These properties make the resulting carboxy-ester a much more uniform product than the feedstocks (vegetable oil). Making biodiesel is a feedstock "upgrading" technology.

Biodiesel is produced by the process called transesterification or esterification where vegetable oil chemically reacts with alcohol in presence of a catalyst. From this reaction Carboxy ester and glycerol are produced as biodiesel and byproduct respectively. The reaction can be performed in four different processes. Among them the mostly used and effective one is alkali-catalyzed process. The catalyst for this reaction is KOH or NaOH. Three moles methanol react with one mol triglyceride.

The reaction of catalytic conversion of vegetable oil into biodiesel is given below:



where R is long hydrocarbon chains, sometimes called fatty acid chains

3. Production of biodiesel

The schematic diagram for the production of biodiesel from vegetable oil is shown in Fig.1.

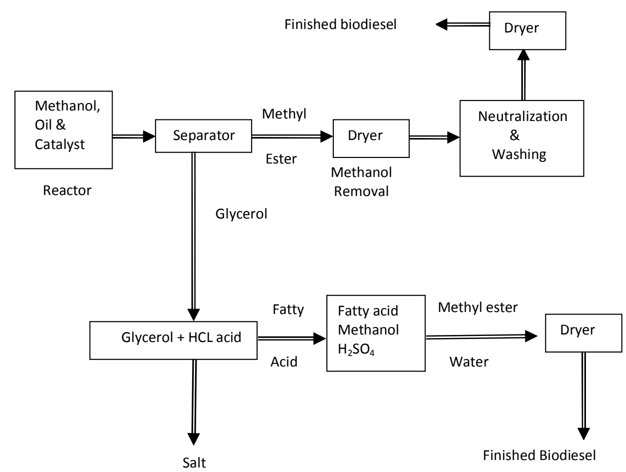


Fig.1 Schematic representation of Biodiesel production

A solution is produced by stirring the mixture of vegetable oil, alcohol and catalyst. The solution is kept at 45-55 °C for 1 to 8 hours. After that two layers are formed- the upper one is biodiesel and the lower one is glycerol. Biodiesel is separated from the glycerol by gravity separation method. To remove alcohol (if present any) from biodiesel, the separated biodiesel is boiled at the boiling temperature of alcohol for the time being. Again, to wash the catalyst from raw biodiesel water is mixed for formation of soap. Finally the pure biodiesel is produced after removing water by boiling at 100°C.

4. Results & Discussion

Table 1 Biodiesel extracted from vegetable oils

No. of obs	Quantity of vegetable oil (ml)	Biodiesel Extracted from soybean oil			Biodiesel Extracted from sesame oil		
		Pure biodiesel (ml)	Percentage of extracted pure biodiesel	Average percentage of extracted pure biodiesel	Pure biodiesel (ml)	Percentage of extracted pure biodiesel	Average percentage of extracted pure biodiesel
1	60	53	88%	89.75%	50	83.3%	82.64%
2	60	54	90%		52	86.6%	
3	60	55	91%		50	83.3%	
4	60	54	90%		48	80%	

Table 2 The observed properties of vegetable oils, biodiesels, and Diesel

Properties	Soybean Oil	Sesame Oil	Jathropa Oil	Diesel	Soybean biodiesel	Sesame biodiesel	Jathropa biodiesel
Kinematic viscosity, ν at 30^0C ($10^6m^2/s$)	32.6	35.5	55	2.6	2.068	2.292	5.34
Density, ρ at 30^0C (g/cm^3)	0.9138	0.9133	----	0.82	0.683	0.6979	0.62
Heating Value (MJ/kg)	39.6	39.3	39.5	44.5	41.57	43.67	41
Flash Point (^0C)	254	260	----	65	96	94	----

The obtained densities of biodiesels extracted from soybean oil and sesame oil are 0.683 g/cm^3 and 0.6979 g/cm^3 respectively. They are found close to the density of diesel (0.82 g/cm^3). The heating values of biodiesel extracted from soybean and biodiesel extracted from sesame oil are 41.57 MJ/kg and 43.67 MJ/kg respectively. Where as the heating value of diesel is 44.50 MJ/kg. The kinematic viscosity of biodiesel extracted from soybean and biodiesel extracted from sesame oil are $2.068*10^6m^2/s$ and $2.292*10^6m^2/s$ respectively while the kinematic viscosity of diesel is $2.068*10^6m^2/s$. From above data of the properties of the biodiesels it is obvious that the biodiesel extracted from the sesame oil is more suitable as an alternative of diesel.

5. Cost Analysis

Table 3 Cost of biodiesel per liter production from soybean oil

Sl. No.	Component	Amount used	Unit price (Tk)	Cost (Tk)
1	Soybean	1 liter	80/L	80
2	Methanol	250 milliliter	720/L	180
3	NaOH	8gm	800/Kg	6.4
	The total cost of	89.75% Biodiesel		266.4

The cost of per liter biodiesel extracted from soybean oil is Tk. 296.82.

Table 4 Cost of biodiesel production from sesame oil

Sl. No.	Component	Amount used	Unit price (Tk)	Cost (Tk)
1.	Sesame	1 liter	120/L	120
2.	Methanol	250 milliliter	720/L	180
3.	NaOH	8gm	800/Kg	6.4
	The total cost of	82.64% Biodiesel		306.4

The cost of per liter biodiesel extracted from sesame oil is Tk. 370.

6. Conclusion

Biodiesel is an important new fuel which could be used as alternative of diesel. It can be produced through a simple chemical process. Its pure form B100 or any of its blend can be directly used in diesel engines with a little or without any engine modifications. The biodiesels from soybean and sesame oil are successfully produced and their properties are tested and compared with petroleum diesel and also other biodiesel available. Finally it can be concluded that-

- A maximum of 89.75% biodiesels from soybean oil and a maximum of 82.75% biodiesel from sesame oil are found to be produced at 25% methanol and 0.8% NaOH.
- The optimum reaction time for maximum biodiesel production from both oils with methanol and NaOH was observed to be around 3-4 hours at 50-55**^{0}C**.
- The heating values of biodiesel extracted from soybean and sesame oil are 41.57 MJ/kg and 43.67 MJ/kg respectively. Where as the heating value of diesel is 44.50 MJ/kg.
- The kinematic viscosities of biodiesel extracted from soybean and sesame oil are $2.068*10^6m^2/s$ and $2.292*10^6m^2/s$ respectively while the same for diesel is $2.068*10^6m^2/s$.
- The cost of biodiesels produced from soybean oil and sesame oil are approximately Tk. 296.82/litre and Tk. 370/litre respectively.
- Sesame biodiesel is found more suitable than soybean biodiesel.
- Though the cost of biodiesels is higher than petroleum diesel but directly it or any of its blend can be used in case of scarcity.

REFERENCES

[1] K.C. Singhal, A. Rahman, Plant-Oil as Diesel-Engine Fuel, *National Conference on I.C Engines and Combustion*. pp 55-62 (1994).

[2] M. S. Rahman, M. N. Nabi, M. R. A. Beg, Performance Study of a Diesel Engine with Diesel-Vegetable oil Blends as Alternative Fuel, *2nd BSME-ASME International conference on Thermal Engineering,* 2-4-January,Dhaka, Bangladesh (2004).

[3] K. K Gandhi, Alternate fuels: A necessity, *Science Report,* PP. 13-16 (1994).

[4] K. Datta, Plant oil–A Suitable Option for Diesel Engine, *Department of Mechanical Engineering, Jadavpur University of Calcutta.700032,* pp 1-3 (1995).

[5] S.P. Rao, K.V. Gopalakrishnan, Vegetables oil and their Methyl esters as fuels for diesel engine, *Indian Journal of Technology*, Vol.29, pp 292-29 (1991).

[6] Alternative Fuels: Biodiesel, *Us.S. Environmental Protection agency EPA420-F-06-044* October (2006).

[7] A.Williams, F.N. Ani, The Use of Plam Oil as an alternative Diesel Fuel, *Fuels for Automotive and Industrial Diesel Engines, The institute of Mechanical Engineers,* London, UK, Nov 20, (1990).

[8] Md. Nurun Nabi, Hustad Johan Einar and Kannan Dhandapani, *First Generation Biodiesel Production from Non Edible Vegetable Oil and Its Effect On Diesel Emissions, Proceedings of the 4th BSME-ASME International Conference on Thermal Engineering;* 27-29 December, Dhaka, Bangladesh (2008).