A review: Advantages and Disadvantages of Biodiesel

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Abstract - *The present paper gives a complete idea on the prospective technology for the production of clean energy in the form of biodiesel. The fast growing society needs energy which should be clean in all the aspects and this can be fulfilled by biodiesel. Due to increasing use of petroleum fuels in automobiles and industrial sectors, in the past few years, the world has started facing severe problems like environmental pollution, ozone layer depletion, global warming. Due to good oxidation characteristics and lubricating nature Biodiesel is attracting the world to its side as the alternative fuel. Therefore, many scientists from different parts of the globe are carrying out research to find an alternative source in order to replace the existing one. Biodiesel can replace the present energy crisis and further help in reducing global warming. Utilization of biofuels results in the reduction of global warming and also helps in maintaining the demand and supply levels of fossil fuels. The present paper gives an idea of different types of fuels available along with comparison of properties of different fuels and their advantages and disadvantages.*

Key Words: biodiesel, Diesel engine, transesterification, performance, emission

1. INTRODUCTION

Energy has the capability to do work and has become a key factor for a process to occur. An energy resource is something that can produce heat, power, life, move objects, or produce electricity. Matter that stores energy is called a fuel. Human energy consumption has grown steadily along with population and final reached a stage of extinction[1]. In today's society, humans consume as much as 110 times of the energy consumed by early human i.e. the developing society needs energy for its running. Most of the energy we use today come from fossil fuels .But fossils fuels have a disadvantage that they are limited in nature , and cause other potentially harmful effects on the environment[2].

1.1 Renewable Resources

Renewable resources are that resources which can be replenished by the environment over relatively short periods of time. This type of resource is much more desirable to use because it can be compensated by the nature. Some examples of renewable energy sources are solar energy, wind energy, hydropower, geothermal energy, and biomass energy[3].

1.2 Non-Renewable Resources

In contrast to renewable resources, non-renewable resources are resources that are not easily replenished by the environment. Earth minerals and metal ores, fossil fuels (coal, petroleum, and natural gas) and groundwater in conditions are considered non-renewable resources.

2. FUELS

In our day to day life we see many machines running around us, for running them some form of energy is required which is provided by the help of fuel**.** A fuel is any material that can be made to react with other substances so that it releases chemical or nuclear energy as which can be utilized directly or can be converted into work. Fossil fuels were rapidly adapted during the industrial revolution because they were cheap and efficient[4]. They have become a major part our society but they have also imputed to pollution. Currently people are more inclined towards usage of renewable fuels such as biofuels.

Biofuels are fuels which are derived from biomass, they can be in solid, liquid and gaseous form. Biomass can be used directly for heating or power or it can be processed to get the maximum benefit from it. Biofuel can be produced from any carbonaceous material .Many different plant derived materials are used for biofuel manufacturing. Ethanol is also a biofuel because it is made from corm[5]. Biodiesel is vehicle fuel made from vegetable oil.

3. ENERGY FROM DIFFERENT FUELS

The amount of energy from different types of fuel depends on the stoichiometric ratio, the AFR ratio and its Specific energy, the energy per unit mass. Air–fuel ratio (AFR) is the mass ratio of air to fuel present in a combustion process such as in an internal combustion engine or industrial furnace.

Table.1 Energy capabilities of common types of fuel

CF	Specific energy (MJ/kg)	AFR stoich.	FAR stoich.	Energy @ $\lambda=1$ (MJ /$kg_{(Air)}$)
Hydrogen	142	34.3 : 1	0.029 : 1	4.140
LPG	46.4	17.2 : 1	0.058 : 1	2.698
Kerosene	46	15.6 : 1	0.064 : 1	2.949
Gasoline	46.4	14.7 : 1	0.068 : 1	3.156
Diesel	48	14.5 : 1	0.069 : 1	3.310
Ethanol	26.4	9 : 1	0.111 : 1	2.933
Methanol	19.7	6.47 : 1	0.155 : 1	3.045
Nitromethane	11.63	1.7 : 1	0.588 : 1	6.841

1 MJ ≈ 0.28 kWh ≈ 0.37HPh

As we can see from the above chart that the main source of energy in India is fossil fuels which is not good for the environment. So we require alternative fuels[4].

4. ALTERNATIVES TO REPLACE FOSSIL FUELS

4.1 Nonconventional energy resources

Energy generated by using wind, tides, solar, geothermal heat, and biomass including farm and animal waste as well as human excreta is known as non-conventional energy[6]. All these sources are renewable or and can be replenished by the environment and do not cause environmental pollution. Moreover they do not require heavy expenditure.

- **Bio-Energy:**

Biomass is considered as an energy source. The energy we get from biomass is bio energy. Some vital forms of biomass are inferior wood, urban waste. Biomass refers to all plant material and animal waste product when pulp, livestock and human waste[7]. It includes both terrestrial as well as aquatic matter such as new plant growth, residues and wastes.

- **BIO-DIESEL**

Bio-diesel refers to a vegetable oil or animal fat based diesel fuel consisting of long chain alkyl (methyl, ethyl, or propyl) esters. Biodiesel is made by chemically reacting vegetable oil, soybean oil, or animal fat with an alcohol produced from different fatty acids[4].

Bio-diesel is employed in standard diesel engines and is therefore distinct from the vegetable and waste oils used in fuel converted diesel engines. Bio-diesel can be used alone, or mixed with petro diesel in certain proportions. Biodiesel is often referred to as monoalkyl ester with long chain fatty acids[8]. Blends of **20%** biodiesel and lower can be utilized in diesel **i**nstrumentation with only minor modifications[6].

5. OILSEED CROPS FOR BIODIESEL PRODUCTION

Biodiesel can be produced from a wide variety of oilseed crops and animal fats. In Europe, rapeseed oil is the major biodiesel feedstock[7]. In the United States soya beans are major biodiesel feedstock. Algae contains 90% of biodiesel contain in it.

5.1 Different oil seed crops for biodiesel production are

- Soybeans
- Mustard
- Rapeseed and Canola
- Camelina
- Sunflower
- Karanja
- Mahua
- Neem oil
- Rice bran oil
- Jatropha

In addition to oil seed crops, biodiesel can be produced from:

5.3 Used and waste oil

Waste oil and grease can be collected from restaurants to produce biodiesel. Whereas the processing costs of this urban source are higher per gallon than the processing costs of virgin vegetable oils.

5.4 Animal Fats

Animal fats are low cost biodiesel feed-stocks. However, there are also some drawbacks and challenges to animal fat feed-stocks[4].

5.5 Algae

Microalgae have long been considered as potentially good sources for biofuel production because of their relatively high oil content and rapid biomass production[5].

6. SELECTION OF FEEDSTOCK FOR BIODIESEL

In general, seeds and nuts should be selected considering all the outcomes and shortcomings, it should be stored in cool and dry conditions, and processed quickly to avoid degradation. The seeds should be processed close to the time when the oil will be processed into biodiesel. Before processing the seeds must be cleaned, screened, and, in some cases, hammered or dehulled[9]. The meal or cake in some cases must be heated to deactivate toxic components before use. Biodiesel is not the same as straight vegetable oil or animal fat. A normal diesel engine will eventually be damaged through the use of straight vegetable oil or straight animal fat fuel. Vegetable oils or animal fats must be converted into biodiesel by reacting the oil or fat with an

alcohol and a catalyst. This process is referred to as "transesterification[4]."

7. MAKING BIODIESEL

Biodiesel is made by reacting vegetable oil or animal fat with an alcohol (methanol or ethanol) and a catalyst. This process separates the glycerin from oil or fat. Thus resulting in biodiesel which is thinner than the original oil or fat and works better in diesel engine[10]. Biodiesel production is the method of producing the biofuel, biodiesel, through the chemical reactions such as transesterification and esterification. This involves vegetable or animal fats and oils being reacted with short chain alcohols (typically methanol or ethanol). The alcohols used should be of low relative molecular mass, ethanol is most commonly used because of its low cost, however greater conversion into biodiesel can be done using methanol[7]. The method of production is base catalyzed transesterification, this process is chosen because it consumes less time and also the cost of catalyst is low. This process is cheaper than the acid esterification[11]. However alkaline catalyst has the disadvantage of high sensitivity to both water and fatty acid present within the oil.

7.1 Transesterification

Animal and vegetable oils are composed of triglycerides, which are esters of three free fatty acids and glycerol. In the transesterification process, the addition of alcohol and alkali de-polymerization occurs, making it a stronger nucleophile. It can be seen that the reaction did not have other inputs than triglycerides and alcohol. Under normal conditions, the reaction will proceed very slowly, so heating is used to accelerate the reaction using a catalyst (acid and / or base). Common catalysts for transesterification include sodium hydroxide, potassium hydroxide and sodium methoxide[6].

The most economical process for processing virgin vegetable oil, which only requires low temperature and pressure and produces more than 98% of the crop. However, biodiesel made from different sources or in other ways may require acidic catalysts, which are much slower[12]. Due to the dominant technique for production almost all biodiesel is made from virgin vegetable oil using basic catalyst techniques because it is action on an industrial scale, only the base catalyzed transesterification method is discussed below.

7.1 Base-catalysed transesterification mechanism

The transesterification reaction is the base catalyzed. Strong bases capable of deprotonating the alcohol can be used, but sodium and potassium hydroxide are generally selected due to their lower prices. The presence of water causes undesired base hydrolysis, so the reaction must remain dry[6].

In the transesterification mechanism, carbonyl carbon from the starting ester (RCOOR1) undergoes a nucleophilic attack by an inlet alkoxide (R2O-) to provide a tetrahedral intermediate, which returns to the starting material, or passes to the transesterification product (RCOOR2). Various species exist in equilibrium and therefore the product distribution depends on the relative energies of reactant and product.

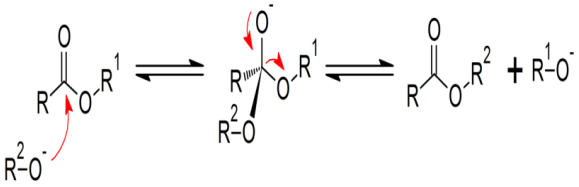

Chart-1 Transesterification reaction

8. DIFFERENT PRODUCTION METHODS

- **Ultra and high shear in line and batch reactors**

Ultra and High Shear Reactors inline or in batches enable continuous, semi-continuous and biodiesel production in batch mode. This drastically reduces production time and increases production volume[4].

The reaction is carried out in the highly energetic zone of the Ultra and High Shear mixer, reducing the size of the incompressible liquid droplets, such as oil or fat and methanol. Therefore, smaller the drop size larger the surface area, which will allow larger catalyst action.

- **Supercritical process**

An alternative, catalyst-free methodology for transesterification uses supercritical methanol at high temperatures and pressures during a continuous method. In the critical state, the oil and methanol are in a single phase, and reaction happens spontaneously and quickly[7]. The process can tolerate water within the feedstock, free fatty acids are converted to methyl esters rather than soap, thus a wide variety of feedstocks may be used. And also the catalyst removal step is eliminated.

- **Ultrasonic reactor method**

In the ultrasonic reactor methodology, the ultrasonic waves cause the reaction mixture to produce and collapse bubbles uniformly. This cavitation at the same time provides the space for blending and heating required to carry out the transesterification process. Thus, using an ultrasonic reactor for biodiesel production drastically reduces the reaction time, reaction temperatures, and energy input. Therefore the method of transesterification will run inline instead of using the time consuming batch processing. Industrial scale ultrasonic devices allow the commercial scale processing of thousands of barrels per day[6].

9. PRODUCT PURIFICATION

Products of the reaction include not only biodiesel, but also byproducts, soap, glycerol, excess alcohol, and trace amounts of water. All of these byproducts must be excluded for perfect blend of biodiesel, but the order of removal is process-dependent. The density of glycerol is greater than that of biodiesel, and this property difference is the key to separate the bulk of the glycerol coproduct. Residual methanol is typically recovered by distillation and reused[13]. Soaps can be removed or converted into acids. Residual water is also removed from the fuel[6].

10. BIODIESEL AS A REMEDY TO CURRENT ENERGY CRISIS

10.1 Biodiesel as a fuel

Biodiesel meets both the biomass-based diesel and overall advanced biofuel demand of the Renewable Fuel standard. Biodiesel is a liquid fuel usually stated as B100 or neat biodiesel in its pure, un homogenised form. Like petroleum diesel, biodiesel is used as fuel in compression-ignition engines. How well biodiesel performs in weather condition depends on the blend of biodiesel[14]. The smaller the proportion of biodiesel within the mix, the better it performs in cold temperatures. Regular No. 2 diesel and B5 perform the same in cold weather.

Table.2 Physical Characteristics of Biodiesel

Specific gravity	0.88
Kinematic viscosity at 40 degree celcius	4.0 to 0.6
Cetane number	48 to 65
Higher heating value, Btu/gal	"127,960
Lower heating value,Btu/gal	119,550
Density, lb/gal at 15.5 deg celcius	7.3
Carbon, wt%	77
Hydrogen, wt%	12
Oxygen, by diff. Wt%	11
Boiling point, deg celcuis	315-350
Flash point, deg celcius	100-170
Sulfur, wt%	0.0 to 0.0015
Cloud point, deg celcius	-3 to 15
Pour point, deg celcius	-5 to 10

Not all the light-, medium-, and heavy-duty diesel vehicles are technically "alternative fuel" vehicles, several are capable of running on biodiesel. Biodiesel that is most frequently used as a blend with regular diesel fuel can be used in several diesel vehicles without any engine modification. The most common biodiesel blend is B20, which is 6% to 20% biodiesel blended with petroleum diesel[4]. B5 (5% biodiesel, 95% diesel) is commonly used in fleets[7]. Before using biodiesel, it's necessary to check the engine's warranty to make sure that higher-level blends of alternative fuel do not void or have an effect on it. Biodiesel improves fuel lubricity and raises the Cetane number of the fuel. Diesel engines depend upon the lubricity of the fuel to stay moving components from wearing untimely. Federal regulations have step by step reduced allowable fuel sulfur to only fifteen parts per million, that has often resulted in lower aromatics content in diesel fuel. One advantage of biodiesel is that it can impart satisfactory lubricity to diesel fuels at blend levels as low as 1%.

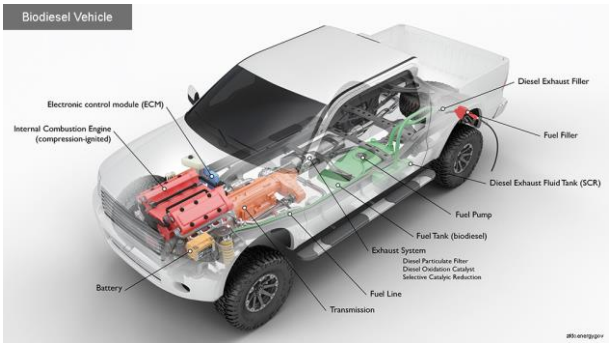

Chart-2 Biodiesel vehicle

Biodiesel fuel can also be used as a heating fuel in domestic and commercial boilers. A blend of heating oil and standardized biofuel is used here. It is sometimes known as "bio heat" and is available in various blends; up to 20%. Using biodiesel fuel existing furnaces without modification is considered acceptable. Increase in the use of biodiesel fuel is projected in the coming years.

10.2 EFFICIENCY

According to a recent study, an average farm consumes fuel at 82 liters of oil per hectare of land to generate one crop. However, a mean crop of oilseed makes oil at an average rate of 1,029 L/ha, and high-yield oilseed fields turn out about 1,356 L/ha. It is clear to notice the ratio of input to output in these cases which is roughly 1:13 and 1:16. Photosynthesis is known to have an efficiency rate of about 3-6% of total solar radiation[6]. Therefore, if the whole crop mass is used for producing energy, the general efficiency of this chain is currently about 1%.

10.3 Comparing emissions

Our testing showed that emissions from the biofuels were the same or better than from regular diesel by most measures. None of the four fuels generated significant amounts of carbon monoxide. Cooking oil produced less smog-causing NOx than regular diesel, while our B100 produced a little more.

Table.3 Properties of Biodiesel

	Diesel	Cooking oil	B100	B5
EMISSIONS				
Unburnt hydrocarbons,ppm	3	14	9	3
Carbon monooxide,%	0	0.01	0	0
NOx, ppm	237	214	248	240
Particles (opacity)	2.9	1.6	1.1	2.4
FUEL ECONOMY				
City, mpg	20.1	20.8	22.3	22.6
Highway, mpg	44.9	42.1	44.2	48.5
ACCELERATION				
0-30 mph, sec.	4.5	4.5	4.5	4.5
0-60 mph, sec.	15	14.9	14.5	14.2
1/4- mile, mph	69.9	70.3	71.3	72.2

11. ADVANTAGES OF BIODIESEL FUEL

- Easy to use: No vehicle modification or any fueling equipment needed.
- Power, Performance and Economy: Proven power generation, performance and cost efficiency made biodiesel a useful fuel.
- Effect on environment: Biodiesel is helping in reducing pollution and improve health by lowering the emission of CO2 which reduces the effect of global warming.
- Biodiesel reduces the use of foreign oils.
- Biodiesel is safer to handle because it is less toxic and easy to store than petroleum.
- Biodiesel helps communities by keeping energy dollars at home.

12. DISADVANTAGES OF BIODIESEL FUEL

- At present, Biodiesel fuel is about one and a half times more expensive than petroleum diesel fuel.
- It requires energy to produce biodiesel fuel from soya crops, plus there is the energy of sowing, fertilizing and harvesting.
- Another biodiesel fuel disadvantage is that it can harm rubber houses in some engines.
- As Biodiesel cleans the dirt from the engine, this dirt can get collected in the fuel filter and clogging occurs. So, filters should be changed regularly.
- Biodiesel fuel distribution infrastructure needs improvement, which is another of the biodiesel fuel disadvantages.

13. CONCLUSION

Biodiesel provides energy security as it protects the environment, and also boosts the economy. Today, biodiesel turning as the growing alternative fuel not only in America, but other parts of the world as well. One of the main reasons behind transition to biodiesel fuel is energy security. Is that the nation's dependence on foreign oil get reduced, use of locally available sources is enhanced. Thus a country finds energy security in biodiesel fuel without a decrease in greenhouse gas emissions. Although the total energy balance is still a debatable issue, but clearly the energy security due to biodiesel fuel is enhanced. It has been observed that properly managed biodiesel fuels have the prospective for strengthening the security of supply and can also help in generating different energies[7].

References:

[1] Nayak,S.K.,Mishra,P.C.,Behera,G.R.2017.Experimentel Investigation on dual-fuel engine utilization waste cooking oil and producer gas. Energy Sources ,Part A:Recovery, Utilization and Environmental Effects. Article in press, Pages 1-8.

[2] A.M. Namasivayam, T. Korakianitis, R.J. Crookes, K.D.H. Bob-Manuel, J. Olsen .Biodiesel, emulsified biodiesel and dimethyl ether as pilot fuels for natural gas fuelled engines Appl Energy, 87 (2010), pp. 769–778

[3] Nayak, C., Pattanaik,B.P.,Nayak, S.K. Effect of preheated Jatropha oil and Jatropha Oil methyl ester with producer gas on diesel engine performance, Volume 9,Issue 1,2014,pages 1709-1722.

[4] Prashanth, B., Saiteja,R., Sunil Kumar,B.,Swarup Kumar Nayak., 'Performance Characteristics of a four Stroke Single Cylinder Diesel Engine Fuelled with Waste Cooking oil and Diesel Blends", Proceedings of International Conference on Emerging Trends in Mechanical Engineering(ICETIME-2016).pp:747-751, 2016.

[5] A.K. Agarwal, K. Rajamanoharan .Experimental investigations of performance and emissions of Karanja oil and its blends in a single cylinder agricultural diesel engine Appl Energy, 86 (2009), pp. 106–122.

[6] Nayak,S.K.,Behera,G.R.,Mishra,P.C.Physio-chemical characteristics of punnang oil and rice husk-generated producer gas,Volume 39,Issue 3,! February 2017,Pages 291-298.

[7] G. Hemanth, B. Prashanth, Nayan Benerjee, Tuhin Choudhuri, Mrityunjay, "Dual fuel mode operation and its emission characteristics in diesel engine with Producer gas as primary fuel and Jatropha biodiesel as pilot fuel",International journal of mechanical engineering and technology, Volume 8, Issue 4, pp:138-147, April 2017.

[8] A. Boretti ,Advantages of the direct injection of both diesel and hydrogen in dual fuel H_2ICE Int J Hydrogen Energy, 36 (2011), pp. 9312–9317

[9]Nayak,S.K.,Mishra,P.C.,Kumar,A.,Behera,G.R.,Nayak,B.Experimental investigation on property analysis of karanja oil

methyl ester for vehicular usage.Volume 39,Issue 3,1 February 2017,Pages 306-312.

[10] K. Mu'azu, A. Mohammed-Dabo, S.M. Waziri, A.S. Ahmed, I.M. Bugaje Development of mathematical model for the esterification of *Jatropha curcas* seed oil JPTAF, 4 (3) (March 2013), pp. 44–52

[11] Nayak,S.K.,Mishra,P.C.Investigation on jojoba biodiesel and producer gas in dual-fuel mode.Volume 38,Issue 15,2 August 2016,Pages 2265-2271.

[12] Nayak,S.K.,Mishra,P.C.Emisiion from utilization of producer gas and mixes of jatropha biodiesel Volume 38,Issue 14,17 july 2016,Pages 1993-2000.

[13] Nayak,S.K.,Behera,G.R.,Mishra,P.C.,Kumar,A.Functional characteristics of jatropha biodiesel as a promising feedstock for engine application,Volume 39,Issue 3,1 February 2017,Pages 299-305.

[14] Nayak,S.K.,Mishra,P.C.Application of neem biodiesel and dimethyl carbonate as alternative fuels,Volume 39,Issue 3,1 February 2017,Pages 284-290.