Biodiesel Production Utilizing Diverse Sources, Classification of Oils and Their Esters, Performance and Emission Characteristics: A Research

Mohamed Kafeel Delvi, Manzoore Elahi M Soudagar, Hurmathulla Khan, Zahoor Ahmed Shariff, Imran Mokashi

ABSTRACT--- The ever increasing utilization of energy has resulted in the nation becoming progressively more dependent on fossil fuels such as oil, coal and gas. The mounting prices of crude oil and natural gas and their impending paucity have raised qualms about the security of energy supply in future, which has severe consequence on the augmentation of a countries economy. The alternative to fossil fuels are the non-conventional energy sources, they are plentiful, renewable, pollution-free and eco-friendly. Therefore, the need to utilize renewable energy sources like solar energy, wind, tide, biodiesel has publicized its significance. Biodiesel is one of the unsurpassed resources that have come to the cutting edge recently. In this article, highly rated research journals on biofuels were referred and a detailed assessment has been conducted to emphasize different aspects to biodiesel engineering. These aspects include biodiesel feed stocks, a range of various methods used in production of biodiesel such as pyrolysis, micro emulsion, dilution and transesterification (alcoholysis). The study was extended to understand the effect of biodiesel blend magnitude on the performance of engine parameters such as brake power (BP), brake thermal efficiency (BTE) and fuel properties like cloud point, flash point, calorific value, kinematic viscosity, density, and cetane number as well as the economic viability, emission characteristics and finally Greenhouse gas emissions.

Keywords— Edible feedstock oil, Non Edible Feedstock oil, Viscous properties, Efficiency O2, CO2, CO and Hydrocarbon .

I. INTRODUCTION:BIODIESEL FEEDSTOCK

Biodiesel fuel is one of the simplest and easiest replacing fuels to utilize. A diversity of oils as biodiesel fuel feed stocks are used to produce the fuel. Across the world, there are more than 300-350 oil-bearing harvest known for huge sources of biodiesel production [1,9,11,22,29,44,50-59]. The abundance availability of feed stocks for biodiesel production one of the significant factors in producing biodiesel. The feedstock should possessed two main parameter: production cost should be low and production scale should be large. For a high-quality yield of high oil bearing it should satisfy geographical locations, the regional climate, agricultural practices and local soil conditions of any country. The conventional and non-conventional feedstock used for the production of biodieselis listed in TABLE 1.These includes edible oils, non-edible oils, waste vegetable oil, animal fats and Oil from halophytes. The most common edible oil and non-edible oils are palm, canola rapeseed, mustard, sunflower, Jatropha, soybean, cottonseed, corn, jojoba oils, olive, coconut, hazelnut, honge pistachio, Neem, sesame, mahua, linseed, and castor[1-5, 9]. According to topography Soybean oil is usually utilized in the USA, rapeseed oil used in European countries, palm oil used in Malaysia, and Jatropha and honge oils are eaten by Indian [11]. TABLE 2 shows primary biodiesel feedstock for few countries around the world. Biodiesel is long-chain fatty acids made up of mono-alkyl esters derivative of animals fats or vegetable oils. In layman's terms, it is a clean-burning substitute fuel made from animal fat or vegetable oil which is chemically processed to remove glycerin. Biodiesel is commonly prepared from non edible lignocelluloses biomass and is the second generation fuel. Biodiesel in pure form refers to the unmodified fuel known as B100 which has been recognized as a substitute fuel by the U.S. Departments of Energy and Transportation. B100 can be utilised in its pure condition, but in general it is used as an additive for diesel fuel. [46,51,52]

TABLE 1. Main feed stocks of biodiesel [1, 9-18,25,36,42,44,49]

Groups	Source of oil
Edible Oils	Soybeans (Glycine max),Safflower, Rice bran oil (Oryza sativa), Barley, Sesame (Sesamum indicum L.), Groundnut, Sorghum, Wheat, Corn, Coconut, Canola, African oil palm (Elaeisguineensis), Sunflower (Helianthus annuus) ,Rapeseed (Brassica napus L.)

Revised Manuscript Received on July 10, 2019

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Non edible oil	Cotton seed (Gossypium hirsutum), Jatropha curcas, Pongamia (Pongamiapinnata), Pongamia (Camelina Sativa), Karanja or honge (Pongamiapinnata), Cumaru, Cynara cardunculus, Mahua (Madhucaindica), Coffee ground (Coffea Arabica), Abutilon muticum, Neem (Azadirachtaindica),Nagchampa (Calophylluminophyllum), Passion seed (Passiflora edulis), Salmon oil, Tall (Carnegiea gigantean), Croton megalocarpus, Pachira glabra, Aleuritesmoluccana, Terminalia belerica Jojoba (Simmondsiachinensis), Rubber seed tree (Hevcabrasiliensis)
Animal Fats	Fish oil, Beef tallow, Chicken fat Poultry fat, Pork lard
Other sources	Algae (Cyanobacteria), Bacteria , Terpenes, Poplar, Switchgrass, Fungi , Miscanthus, Latexes, Microalgae (Chlorella Vulgaris),

TABLE 2. Current potential feed stocks for biodiesel worldwide [1,11,15-19,39,44]

Country	Feed stocks
Argentina	Soybean
Brazil	Soybean/palm oil/castor/cotton oil
Canada	Rapeseed/animal fat/soybeans/yellow grease and tallow/mustard/flax
China	Jatropha/waste cooking oil/rapeseed
France	Rapeseed/sunflower
Greece	Cottonseed
India	Jatropha/PongamiaPinnata/Mahua (Karanja)/soybean/rapeseed/sunflower/peanut
Indonesia	Palm oil/Jatropha/coconut
New Zealand	Waste cooking oil/tallow
Spain	Linseed oil/sunflower
USA	Soybeans/waste oil/peanut

2. NON-EDIBLE FEED STOCKS

Today, edible oil only can't be used as fuel in to days date to meet the huge demand of fuel due to various reasons. Under these circumstances, those feed stocks can be considered which produce oil insignificant quantity from non-edible oil feedstock and Following are few non-edible feed stocks . The edible oils like soybeans, palm oil, rapeseed, , coconut, and sunflower, which produces more than 90 percent of the planet's biodiesel. The plants of edible oils are well recognized in a lot of countries in the world such as USA, Germany, Australia, Malaysia, etc. At present, however, their use raises many apprehensions such as food versus fuel crisis. Furthermore, in the preceding 10 years the prices of vegetable oil plants have amplified radically which will influence the economic feasibility of biodiesel industry [17, 37]. The usage of biodiesel from edible feedstock is not favorable for long run because of the increasing gap of demand and supply of edible oils in numerous countries. The potential solutions to minimize the consumption of the edible oil for biodiesel purpose through utilizing non-edible oils. Non-edible oils feed stocks are gaining universal consideration because they are easily available around the world especially wasteland like forests, deserts, mountains, etc that are not suitable for edible crops, they eradicate competition for food, decline in deforestation rate, ecologically affable, and they are very inexpensive comparable to edible oils

Jatropha curcas (Jatropha)


Calophylluminophyllum (Tamanu oil)


Pongamiapinnata (Karanja/ Honge)


Azadirachtaindica (neem)

Garcinia indica seeds and oil

Thevetia peruviana (Yellow Oleander)

Sapindusmukorossi(Soap Nut)

Ricinus Communis (Castor)

Melia azedarach (Chinaberry)

Argemone Mexicana (Mexican prickly poppy)

FIGURE 1. Main biodiesel Non-edible feed stocks [29,37,45]

3. ENGINE PARAMETERS AND PERFORMANCE & RESULTS

The engine performance parameters related to biodiesel are mentioned below and the values for different feed stocks are explained in the Table 3

Viscosity

It affects the working of the fuel injection and spraying equipments. Kinematic viscosity of biodiesel is ten to fifteen times higher than diesel due larger molecular mass and its chemical structure. The maximum permissible limit according to ASTM D445, ranges are (1.9–6.0 mm^2/s) and (3.5–5.0 mm^2/s) [11,17,32,36].

Density is measured at the temperature range of 15 to 20oC according to EN ISO 3675/12185 and ASTM D1298 20^{O}C [40].

Relative density

It is the density of the oil compared to the density of water. If a substance's relative density is less than one then it is less dense than the reference; if greater than 1 then it is denser than the reference. If the relative density is exactly 1 then the densities are equal; that is, equal volumes of the two substances have the same mass. The relative density of biodiesel is needed to make mass to volume conversions, calculate flow and viscosity properties, and is used to quantify the homogeneity of biodiesel tanks [29,41,43].

Flashpoint

Biodiesel has very high flashpoint that is near 150^{O}C than conventional diesel fuel, which has a flash point of 55–66 ◦C [41].

ASTM D2500 EN ISO 23015 and D97 procedures are used to measure Cloud point and Flash point. [41,42]

Cetane number (CN)

Biodiesel observed higher cetane number as compared to diesel fuel [12].

Oxidization stability

The chemical composition of biodiesel helps fuels more vulnerable to oxidative degradation than fossil diesel fuel [9].

Brake power Output (BP)

The brake power of engines operating on pure plant oils or blends varies 10 to -18 % as compared to desiel engine. Variation results are due to higher viscosity during injection, which leads to poor atomization and also incomplete combustion; it also causes some plant oil to be left unburnt and enter in the engine crankcase which leads to absorption of power, plant having low calarofic value caused in reduction of cylinder pressure as compare to today’s fossils fuel [43].

Brake specific fuel consumption (BSFC)

The BSFC of plant oil is the similar or superior to fossil diesel fuel [30, 43]

Brake thermal efficiency (BTE)

Brake thermal efficiency is low due low volatility and High viscosity. [42, 43].

TABLE 3.Physiochemical properties of universally used biodiesel feed stocks [24,29,33-44]

Oil or Fats	**Density 15 ℃ (kg/m^3)**	**Kinetic viscosity at 40℃ (mm^2/s)**	**Cetane No (℃)**	**Flash Point (℃)**	**High heating value (MJ/kg)**	**Cloud point (℃)**	**Calorific value MJ/kg**	**Pour point (℃)**	**Iodine No (℃)**	**Acid (neutralization) value (mg KOH/g)**
Canola	–	4.42	37.6	160	39.7	-3.3	–	-9	–	0.01
Soybean	913.8	4.039	37.9	254	39.6	0.9	39.76	–	128-143	0.266
Sunflower	880	4.439	49	160	39.6	3.4	–	–	–	0.027
Palm	864.42	4.5	54.6	135	–	16	–	15	54	0.24
Peanut	848	4.42	53.59	166	39.8	0	40.1	-8	67.45	0.28
Safflower	885.5	5.8	56	148	–	-5	38.122	–	–	–
Mesua	898	6.2	54	112	39.5	–	42.23	3	–	0.01
Rice Bran	872	4.811	51.6	430	–	–	41.38	269	–	0.48
Maclura	889	4.66	48	180	39.4	-5	–	-9	125	0.4
Cotton seeds	875.7	4.09	51.43	150	39.4	7	40.43	6	–	0.16
Jatropha	879.5	4.8	51.6	135	38.65	2.7	39.23	2	104	0.4
Neem	868	5.213	–	76	–	9	39.81	2	–	0.649
Karanja	931	6.13	55	95	–	7	43.42	3	–	0.42
Mahua	874	3.98	65	208	36.0	–	36.8	6	–	0.41
Linseed	874	3.752	52	160	39.3	-3.8	–	-15	–	0.058
Coconut	807.3	2.726	–	114.8	–	–	–	–	–	0.106
Rapeseed	882	4.43	54.4	170	37.4	-3.3	37	-12	–	–
Tobacco	888.5	4.23	51.6	165.4	–	–	–	–	136	0.3
Beef tallow	–	4.624	–	–	–	–	–	–	–	0.147
Roselle	880.1	4.588	–	130	–	–	–	-1	62	0.43
Okra	876	4.01	55.2	156	–	1.10	–	2.12	–	0.38
Rubber	–	5.81	–	130	–	4	36.5	-8	–	–
Coffee	–	4.852	–	160	–	0.2	–	–	–	0.076
Diesel	850	1.3-4.1	40-55	60-80	42	-20	42-46	-35	38.3	0.062
Calophyll-um Inaphyllu-m	888.6	7.72	51.9	151	–	38	–	–	85	0.76

II. Biodiesel production technologies

The methodologies for biodiesel production are transesterification, pyrolysis and micro-emulsion. Worldwide, many researchers are developing and improving vegetable oil properties in order to estimate the properties of diesel fuels. The low volatility, high viscosity, and polyunsaturated characters are the common problems associated problems with crude vegetable oils and the problems can be overcome by the above mentioned process [1,6,11,12,16,22,44,47].

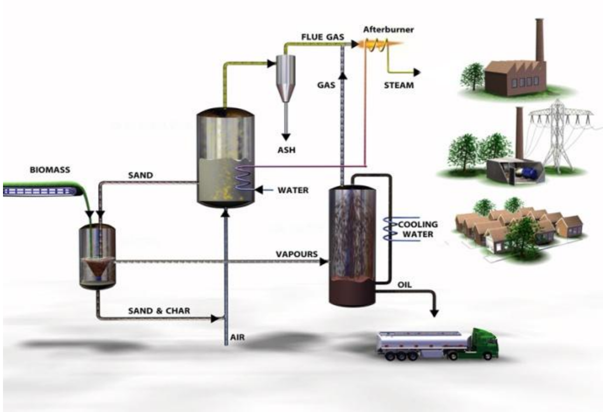

FIGURE 2. Pyrolysis [49]

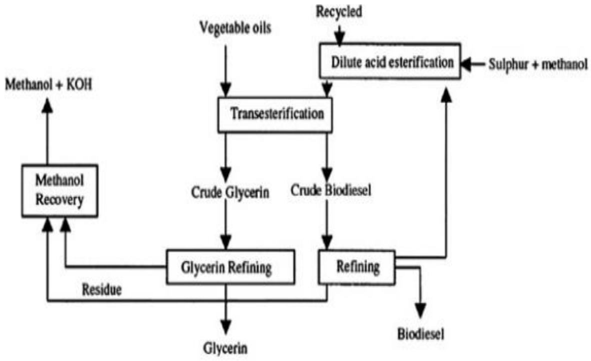

FIGURE 3.Transesterification [48]

Transesterification

One of the best suitable method for production of biodiesel is the Transesterification, it is considered as the unsurpassed method among other methods due to its economic viability and plainness. Transesterification process follows a number of successive, reversible reactions, the detailed process is shown in Fig. 3. The triglycerides are converted first into diglycerides, then monoglyceride and finally into glycerol the glycerol is the by-product which settles down at the bottom, which is used as feedstock in the cosmetic industry and biodiesel is extracted and washed which floats on top, The two main light alcohols used are methanol and ethanol used for transesterification process due to their moderately low cost. [9,11,22,42,44,46]

Micro-emulsion

Micro-emulsion is the colloidal equilibrium dispersion of optically isotropic fluid microstructure with dimensions generally into 1–150 nm range formed spontaneously from two immiscible liquids and one and more ionic or more ionic amphiphiles. Many researchers have been worked on Micro-emulsions using solvents such as butanol, 1-butanol hexanol , ethanol, and methanol. With these solvents caused increase in viscosity need for diesel fuel. [11,44]

Pyrolysis

The thermal decomposition of the organic matters in the absence of air and in the presence of a catalyst is known as Pyrolysis. The detailed process is shown in Fig. 2. The decomposing material can be vegetable oils, natural fatty acids, animal fats or methyl esters of fatty acids. Many researcher have studied the pyrolysis of triglycerides to get suitable fuels for diesel engine. Thermal decomposition of triglycerides produces carboxylic acids, alkadines, aromatics, alkanes and alkenes. Pyrolysis process is pollution free, very effective with less effort . [11,33,42,44]

Dilution

Generally, vegetable oils are mixed and diluted with diesel to decrease the viscosity and progress the performance of engine. This method does not need any chemical reaction [17,44]. Singh,. et al. reported a blend of 20% vegetable oil and 80% diesel fuel was successful rather in diesel engines rather than 100% vegetable oil [11]. Dilution usually consists of the use of blends of diesel fuel with waste cooking oil, African pear seed, coconut oil, oil rubber seed oil, sunflower oil, palm oil, cottonseed oil, soybean oil, rice bran, rapeseed oil and many more. For instance, 25% of sunflower oil mixed with 75% of diesel fuel (in ratio of 25:75) or B25 in a direct injection diesel engine was investigated [95]. The authors observed that this mixture was not adaptable for long-standing use in direct injection engines. The maximum prescribed viscosity value according to ASTM is 4.0cSt at 313 K, but it exceeded that. [44,47].

BIODIESEL EMISSSIONS

Biodiesel fuel is the solelynon-conventional fuel to have efficiently completed the Health Effects Testing requirements of the Clean Air Act (1990).

Almost 50 percent particulate emissions is reduced as contrast with fossil fuelled diesel. Having a superior cetane rating than petro-diesel, some optimistic effects of biodiesel fuel on atmosphere can be seen as it can progress performance and reduce emissions. The data from EIA, US Energy and Administration suggests biodiesel is derived from the plants that are the sources of the feed stocks . Biodiesel is considered a carbon neutral product because the CO_2 is absorbed by the plants such as soybeans and palm oil trees while making and burning biodiesels. Biodiesel reduces the emission of Carbon Monoxide (CO), Nitrogen Oxide (NO_X), unburned Hydrocarbons (HC) [1,4,27,30,43]. Fig 4 describes the basic emissions effects, overall the emissions percentages are lower compared with the diesel fuel. However while using biodiesel the engine output power and mechanical efficiency were reduced and fuel consumption was increased [15]. A number of researchers worked in blending the oil feed stocks and used mixture of diesel fuel to enhance the properties of biodiesel [16–20]. S. Senthilkumar., etal. and Jalpit B. Prajapati,.et al. observed the biodiesel mixing (B5, B10 and B15) results in decrease in fuel consumption,carbon di oxide, carbon monoxide and Hydrocarbon emission as contrasted with diesel fuel. In four stock desiel engine were tested using palm biodiesel as Pyrolysis. The detailed process is shown in Fig. 2. The decomposing material can be vegetable oils, natural fatty acids, animal fats or methyl esters of fatty acids. Many researcher have studied the pyrolysis of triglycerides to get suitable fuels for diesel engine. Thermal decomposition of triglycerides produces carboxylic acids, alkadines, aromatics, alkanes and alkenes. Pyrolysis process is pollution free, very effective with less effort . [11,33,42,44]

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Increasing in engine brake power result in decreased of CO emissions. Fig. 6 suggests the effect of soybean, rapeseed and animal tallow biodiesels, the percentage of emission for CO was lower for animal fat compared to soybean and rapeseed. The experimentation conducted by M.S. Gad et. al using the blends B20, B100 and PO20 demonstrated, due to good quantity of oxygen molecules and lower proportion of carbon content in biodiesel blends as compared to that of diesel fuel which helps in good combustion and as result reduction in carbon monoxide emission. The presence of oxygen in the molecular structure of biodiesel are one of reason for better combustion. [53, 54]

Since biodiesel is having higher oxygen content than diesel fuel, NO_X emissions behaves proportional to percentage of biodiesel and oil in biodiesel and oil blends. Fig. 5 suggests the effect of soybean, rapeseed and animal tallow biodiesels, the percentage of NO_X was higher for animal fat compared to soybean Zeldovich,. et al. cited

For all testing condition observed that with increase in engine load, NO_X emissions increased, as result temperature of cylinder also increased which also became responsible for Higher NO_X formation an d emission with addition to presence of oxygen[30,43,54]. Resulting oxygen content increased with mixing of biodiesel to diesel which lead to better combustion as result hydrocarbon emission are lowered .Emprovement in proportion of oxygen leads to reduction in hydrocarbon emission which can also be attributed to cetane [55]. Fig. 5 represents the effect of soybean or rapeseed and animal tallow biodiesels, the percentage of emission for Particulate Matters (PM) was lower for animal fat compared to soybean. Overall the PM will reduce using the biodiesel ascompared to the diesel fuel.

Greenhouse Gas (GHG) emissions

Biodiesel having capacity to decrease greenhouse emission as compared to fossils fuel based on various factor. Carbon Di oxide is one of the main green house gas which involve in nurture of all green plants. When it turned to biodiesel from biomass, used to run engine as result entire GHG emission will be occurred. Pretentious to today's production methods, with no land use change, biodiesel from sunflower and rapeseed oil produce 45%-65% lower GHG emissions than petro-diesel. But calculation of carbon intensity of biodiesel fuels is a difficult and also inaccurate. Nevertheless, there is ongoing research for improving the effectiveness of the production process of the biodiesel.

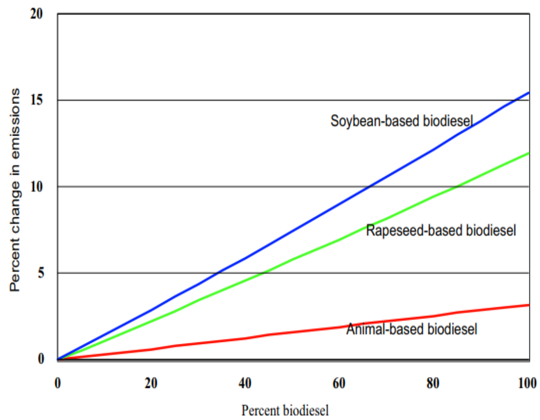

FIGURE 4. Basic emissions effects [56,57]

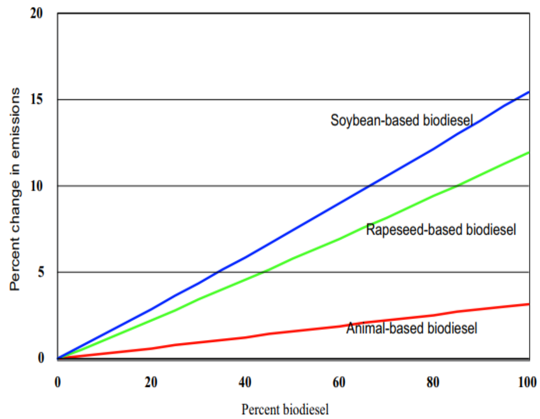

FIGURE 5. Type of Biodiesel – NO_X [57]

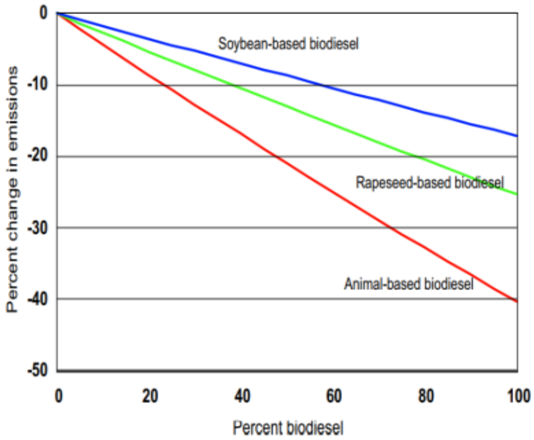

FIGURE 6. Type of Biodiesel – CO[56]

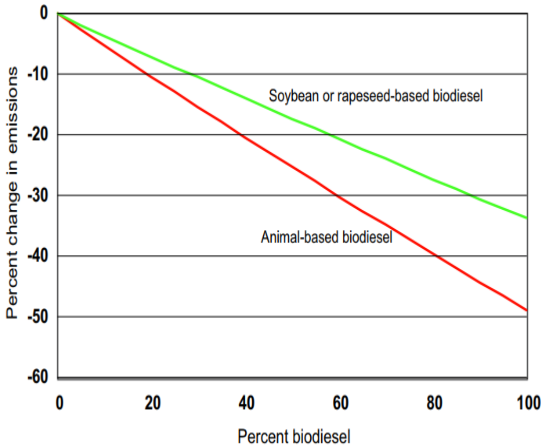

FIGURE 7. Type of Biodiesel – PM[57]

As Biodiesel burns clean, this suggests there will be a major decline an all sort of pollutants adding to smog and global warming. It is the only non-conventional fuel which has been standardized and approved by the Environmental Protection Agency (EPA). In addition, it has conceded every Heath-Effects Test of the Clean Air Act and fulfils the requirements of the California Air Resources Board (CARB).

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