Study of Different Types of Bio-Fuels as Fuel in Diesel Engines : A Review

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ABSTRACT

This paper gives a critical review and recent development done on the biodiesel made from different types of edible and non edible oil derived from various renewable plant seed oils and animal fats, which shows the improved engine performance and reduced exhaust emission. It's also highlighting the global trend in bio-fuel demand and supply, its economic viability, environmental issues and also about the next generation eco friendly bio-fuel which may also help to overcome the issues related to dependence and depletion of conventional fossil reservoirs. Paper gives a summary of research on the Biodiesel derived from various renewable plant seed oils and animal fats is a promising alternative to fossil diesel fuel.

Keyword:- *Critical review, Bio-fuel, Global trend, Economical, Eco friendly, Next generation bio fuel.*

Introduction

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever increasing energy needs requiring huge investments to meet them. The use of bio-fuels like alcohol, vegetable oil and biogas produced from various inputs in diesel engine could reduce the two major crises namely the fossil fuel depletion and environmental pollution [1]. In this century, fuels derived from crude oil have been the major source of the world's energy as well as transportation sector. Known fossil energy sources have been exhausted rapidly nowadays, it is predicted that fossil sources will be depleted in the near future [2]. Increasing uncertainty about global energy production and supply, environmental concern due to the use of fossil fuels, and the high price of petroleum products are the major reasons to search for alternatives to petro-diesel [3].

Biodiesel is advised for use as an alternative fuel for conventional petroleum-based diesel chiefly because it is a renewable, domestic resource with an environmentally friendly (eco friendly) emission profile and is readily biodegradable [4].Diesel fuel is the main energy supply source for transport sector, is also one of the causes of CO_2, HC, CO, NO_X and SO_X emissions that affect air quality. The production of biodiesel is an opportunity to decrease the diesel use. It then presents a favorable position to process biodiesel considering its ecological contribution on conventional fuel [5]. Bio diesel, produced from different vegetable oils (soybean, rapeseed, sunflower, jatropha, Pongamia pinnata(Karanja), cotton seed, mahua, honge, eucalyptus oil etc.), have been used in internal combustion engines without major modifications, with only slightly decreased performance [6].

Types of bio-fuels

Bio-fuels, like fossil fuels, come in a number of forms and meet a number of different energy needs. The class of bio-fuels is subdivided into four generations, each of which contains a number of different fuels.

First Generation Bio-fuels

First Generation bio-fuels are produced directly from food crops by abstracting the oils for use in biodiesel or producing bio ethanol through fermentation. Crops such as wheat and sugar are the most widely used feedstock for bio ethanol while oil seed rape has proved a very effective crop for use in biodiesel. However, the most contentious issue with first generation bio-fuels is ‘fuel vs food’. This has been blamed for the global increase in food prices over the last couple of years. First generation bio-fuels are the “original” bio-fuels and constitute the majority of bio-fuels currently in use [7]

Second Generation Bio-fuels:

Second generation bio-fuels are “greener” in that they are made from sustainable feedstock. In this use, the term sustainable is defined by the availability of the feedstock, the impact of its use on greenhouse gas emissions, its impact on biodiversity, and its impact on land use (water, food supply, etc.). At this point, most second generation fuels are underdevelopment and not widely available for use [8].

Bio-fuels made from unimportant croplands unsuitable for food production, or using non-food crops and residues, where the biomass is consumed in production. Cellulosic ethanol technology fits in here, as do non-food crop technologies such as jatropha-based biofuels. Fischer-Tropsch and other biomass like Coskata, Rentech, Lignol, POET, BP Bio-fuels, DuPont Danisco, Verenium, Cobalt Technologies, Range Fuels, ZeaChem and BlueFire ethanol etc.

Second Generation bio-fuels have been developed to overcome the limitations of first generation bio-fuels. Second Generation bio-fuels are also aimed at being more cost competitive in relation to existing fossil fuels

Third Generation Bio-fuels

The third generation bio-fuel recently enter the mainstream it refers to biofuel derived from algae. Previously, algae were lumped in with second generation biofuels. However, when it became apparent that algae are capable of much higher yields with lower resource inputs than other feedstock, many suggested that they be moved to their own category. As we will demonstrate, algae provide a number of advantages, but at least one major shortcoming that has prevented them from becoming a runaway success [8].

Fourth Generation Bio-fuels

Four Generation Bio-fuels are aimed at not only producing sustainable energy but also a way of capturing and storing CO_2. Biomass materials, which have absorbed CO_2 while growing, are converted into fuel using the same processes as second generation bio-fuels. This process differs from second and third generation production as at all stages of production the CO_2 is captured using processes such as oxy-fuel combustion. [9]

Ethanol (C_2H_5OH)

Ethanol is a renewable source of energy, it can be made from many raw materials or agricultural products such as sugar cane, molasses, cassava root, waste biomass materials, sorghum, corn, barley, sugar beets, etc. by using already improved and demonstrated technologies like alcoholic fermentation process. Ethanol is a low cost oxygenate with high oxygen content of 34% by weight [10].

India is the fourth largest ethanol producer after Brazil, the United States and China, its average annual ethanol output amounting to 1,900 million litres with a distillation capacity of 2,900 million litres per year.

Ethanol, currently produced in India by the fermentation of sugarcane molasses, is an excellent bio-fuel and can be blended with petrol. Likewise, biodiesel which can be manufactured by the transesterification of vegetable oil can be blended with diesel to reduce the consumption of diesel from petroleum. India is now the world's largest sugar consumer and this has put added pressure on the ethanol industry. Ethanol and biodiesel are gaining acceptance worldwide as good substitutes for oil in the transportation sector [11].

Biodiesel

Biodiesel is one of the promising alternative fuels that are technically feasible, environmentally acceptable, economically competitive and readily available. Moreover, biodiesel fuel has become more attractive because of its environmental benefits, due to the fact that plants and vegetable oils and animal fats are renewable biomass sources. Compared to petroleum diesel, biodiesel has lower emission of pollutants, it is biodegradable and enhances the engine lubricity and contributes to sustainability [3]. It has similar physico-chemical properties of conventional fossil fuel and can consequently, entirely or partially substitute fossil diesel fuel in compression ignition engines [4].

Diesel fuel is the main energy supply source for transport sector, is also one of the causes of CO2 emissions. The production of biodiesel is an opportunity to decrease the diesel use. Another advantage of incorporating biodiesel into the transportation sector from the energy point of view is that biodiesel is a renewable energy source. Likewise, the use of biodiesel can extend the life of diesel engines because it is more lubricating than diesel. Biodiesel is the only alternative fuel that runs in any conventional diesel engine without requiring major modifications [5].

Biodiesel is environmentally friendly and can eliminate or decrease engine emissions such as unburned hydrocarbons (68%), particles (40%), carbon monoxide (44%), sulfur oxide (100%), and polycyclic aromatic hydrocarbons (80–90%).Vegetable oils require some modification before the oils can be used in diesel engines. While dilution, thermal cracking (Pyrolysis), and micro-emulsification are various methods used to modify vegetable oil, transesterification is the most common conversion process [12].

Biodiesel produced from vegetable oil or animal fats by transesterification with alcohol like methanol and ethanol is recommended for use as a substitute for petroleum-based diesel mainly because biodiesel is an oxygenated, renewable, biodegradable and environmentally friendly bio-fuel with similar flow and combustion properties and low emission profile [13].

Review of different types of biodiesel feed stocks

In general, biodiesel feedstock can be categorized into three groups: vegetable oils (edible or non-edible oils), animal fats, and used waste cooking oil including triglycerides [14]

Straight Vegetable oil as diesel fuel

Vegetable oil is one of the renewable fuels. Vegetable oils have become more attractive recently because of its environmental benefits and the fact that it is made from renewable resources. Different types of vegetable oils have different types of fatty acids. The fatty acids found in the vegetable oils.

Vegetable oils have the potential to substitute a fraction of petroleum distillates and Petroleum-based petrochemicals in the near future. The basic constituent of vegetable oils is triglyceride. Vegetable oils comprise 90 to 98% triglycerides and small amounts of mono- and diglycerides.

The advantages of vegetable oils as diesel fuel are their portability, ready availability, renewability, higher heat content, lower sulfur content, lower aromatic content, and biodegradability. The main disadvantages of vegetable oils as diesel fuel are higher viscosity, lower volatility, and the reactivity of unsaturated hydrocarbon chains [14].

Edible vegetable oil as biodiesel feedstock

Biodiesel has been mainly produced from edible vegetable oils all over the world. More than 95% of global biodiesel production is made only from edible vegetable oils. Between marketing years 2004 and 2007, the global use of edible oils increased faster, than its production. The projected increase in edible oil use for biodiesel production was approx 6.6 million tons from 2004 to 2007, which would contribute 34% of the increase in global consumption to biodiesel. Biodiesel use of edible oils is estimated to account for more than a third of the expected growth in edible oil use between 2005 and 2017.

Biodiesel is mainly prepared from conventionally grown edible oils such as rapeseed, soybean, sunflower and palm thus leading to alleviate food versus fuel issue. Serious problems face the world food supply today. The rapidly growing world population and rising consumption of bio-fuels are increasing demand for both food and bio-fuels [14].

Non-edible vegetable oil as biodiesel feedstock

Use of non-edible vegetable oils when compared with edible oils is very significant in developing countries because of the tremendous demand for edible oils as food, and they are far too expensive to beused as fuel at present.

The production of biodiesel from different non-edible oilseed crops has been extensively investigated over the last few years. Some of these non-edible oilseed crops include jatropha tree (Jatropha curcas), karanja (Pongamia pinnata), tobacco seed (Nicotiana tabacum L.), rice bran, mahua (Madhuca indica), neem (Azadirachta indica), rubber seed tree (Hevea brasiliensis), and microalgae [14].

Animal fats as biodiesel feedstock

Another group of feedstock for biodiesel production is fats derived from animals. Animal fats used to produce biodiesel include tallow, choice white grease or lard, chicken fat and yellow grease. Compared to plant crops, these fats frequently offer an economic advantage because they are often priced favorably for conversion into biodiesel [14].

Waste cooking oil (WCO) as bioiesel feedstock

Waste cooking oil (WCO) is now a very promising alternative to virgin edible vegetable oil for biodiesel production. WCO would be a good choice as raw material in order to reduce the cost of production, since it is cheaper than virgin vegetable oils. Its price is approx 2–3 times cheaper than virgin vegetable oils. The conversion of WCO into ethyl or methyl esters through the transesterification process approximately reduces the molecular weight to one-third, reduces the viscosity by about one-seventh, reduces the flash point slightly and increases the volatility marginally, and reduces pour point considerably. The production of biodiesel from WCO is challenging due to the presence of undesirable components such as free fatty acids (FFAs) and water.

There is huge amount of WCO generated in each country and varies depending on the use of vegetable oil. A significant challenge is faced by management of WCOs because of its disposal problems and possible contamination of the water and land resources. Even though some of this WCO is used for soap production, a major part of it is discharged into the environment also large amounts of WCO are illegally dumped into rivers and landfills, causing environmental pollution, hence the use of WCO to produce biodiesel as petroleum-based diesel fuel substitute offers significant advantages because of the reduction in environmental pollution and fossil fuel depletion. Therefore, biodiesel derived from WCO has taken a commercial patent as an alternative fuel to petroleum-based diesel fuel for diesel engines. [14].

Global trends in bio-fuel supply and demand

Global production of bio-fuels has been growing rapidly in recent years, more than tripling from about 18 billion litres in 2000 to about 60 billion litres in 2008. Supply is dominated by bio ethanol, which accounted for approximately 84% of total bio-fuel production in 2008. Despite this exponential increase, bio-fuels still represent a very small share of the global energy picture. Total biomass accounted for 3.5% of total primary energy supply in 2007, according to the OPEC World Oil Outlook (OPEC WOO 2009), with liquid bio-fuels accounting for about 0.28% of total energy demand and about 1.5% of transport sector fuel use (IEA WEO 2009).

Currently, production is concentrated in a small number of countries (Table 1). Together the US and Brazil account for about 81% of total bio-fuel production and about 91% of global bio ethanol production Since 2005, the US has surpassed Brazil as the largest bio ethanol producer and consumer, accounting for 50% of global production in 2008 (SCOPE 2009). The EU follows as the third major producer with 4.2%. In contrast, about 67% of biodiesel is produced in the EU, which is also the largest consumer, with Germany and France combined accounting for 75% of total EU production and 45% of global production.

Table 1 Bio- fuel production in 2008, by country

Billon litres (world)	Bio ethanol	Biodiesel	Total bio fuel	Share in total
WORLD	67.0%	12.0%	7.9%	100%
U.S	34.0%	2.0%	36.0%	45.6%
BRAZIL	27.0%	1.2%	28.2%	35.7%
E.U	2.8%	8.0%	10.8%	13.7%
CHINA	1.9%	0.1%	2.0%	2.5%
CANADA	0.9%	0.1%	1.0%	1.3%
INDIA	0.3%	0.02%	0.32%	0.4%

According to a recent study by Hart's Global Bio-fuels Center (Hart/GBC 2009), global demand for ethanol and biodiesel combined is expected to nearly double between 2009 and 2015 from 95.3 to 183.8 billion litres. Ethanol, while accounting for 80% of this latter figure, will only represent 12% to 14% of total global gasoline demand. Although global ethanol supply generally matches demand in 2009 and 2010, it is expected to exceed it in 2015, reaching 168.6 billion litres compared to expected demand of 147.3 billion litres.

Similarly, biodiesel supply is projected to almost double by 2015, reaching 94 billion litres, and will also exceed the estimated demand of 36 billion litres that year. Hart/GBC estimates supply based on current capacity and projected capacity to be in place by the 2015 time frame. Hart/GBC based their demand figures on the assumption that policy requirements and targets will be implemented and fulfilled and by using gasoline and on-road diesel demand figures estimated in another Hart/GBC study.

The supply/demand medium-term outlooks (2009, 2010 and 2015) for major ethanol and biodiesel producers and consumers are summarized in Table 2 [15,16].

Table 2 Global biodiesel medium- term supply/ demand outlook

Billion litre, country	2009		2010		2015	
	Supply	Demand	Supply	Demand	Supply	Demand
World	48.2	13.1	59.6	18.3	94.4	36.5
USA	2.8	2.8	3.1	3.1	8.4	8.4
Brazil	2.9	1.0	4.5	1.8	6.0	2.1
E.U	18.6	9.6	21.5	12.8	28.1	16.1
India	1.8	0	2.0	0	4.2	4.1

LITERATURE REVIEW

M. Pugazhvadivu et al. in 2005 use waste frying oil a non-edible vegetable oil, they evaluated the effect of temperature on the viscosity of waste frying oil and found that the viscosity of waste frying oil at 135^{0}C is same as that of diesel at 30^{0}C. The performance and exhaust emissions of a single cylinder diesel engine was evaluated using diesel, waste frying oil (without preheating) and waste frying oil preheated to two different inlet temperatures (75 and 135 8C). The engine performance was improved and the CO and smoke emissions were reduced using preheated waste frying oil.

Zafer Utlu and Mevlut Sureyya Kocak in 2008 used methyl ester prepared from waste frying oil as an experimental material in turbocharged direct injection four cylinder diesel engine, they determined the physical and chemical properties of waste frying oil from laboratory and compared the test with No 2 Diesel fuel and found that amount of emission of CO, CO2, NOX and smoke dearness of waste frying oil are less than No 2 Diesel fuel.

Arjun B. Chhetri et al. in 2008 collected waste frying oil from a restaurant and prepared their ethyl ester. They determined their physical and chemical properties and compared it with ASTM standard for quality assurance. From the test they found viscosity = 5.03 mm^2/sec at 40^0C flash point to be164^0C, phosphorous content was 2 ppm, calcium and magnesium were 1 ppm combined, cetane index was 61, cloud point was -1^0C and pour point was -16^0C.

A.B.M.S. Hossain and A.N. Boyce in 2009 compared the transesterification process of biodiesel production from pure sunflower cooking oil (PSCO) and waste sunflower cooking oil (WSCO) using alkaline catalyst Result showed that the biodiesel production from PSCO and WSCO exhibited no considerable differences.

Ana M. Vázquez et al. in 2011 does a economic analysis of Biodiesel production from waste frying oil in Mexicali, Baja California, based on the analysis it is derived that the production of biodiesel from waste frying oil in Mexicali is profitable, the percentage of profit is 23.5 % , benefit to cost ratio is 1.05 therefore it is slightly positive.

K. Muralidharan, D. Vasudevan in 2011 performed an experimental test on variable compression (18:1, 19:1, 20:1, 21:1, 22:1,) single cylinder diesel engine using waste frying oil methyl ester and its (20%, 40%, 60%, 80%) blends at fixed RPM 1500 and 50 % load for performance, emission and combustion characteristics. They found that maximum thermal efficiency at 50 % load for B40 blend.

M. Berrios et al. in 2011 performed three operations for purification of biodiesel made from waste frying oil under condition that have been kept as close to commercial operating practice as possible. firstly adsorption (magnesium silicate and bentonite); secondly liquid–liquid extraction (distilled water, tap water, glycerol); and lastly ion exchange (cation resin). The results show that all the purification methods can remove soap, methanol and glycerol effectively [17].

Jagannath Balasaheb Hirkude et al. in 2012 done a test for performance and emission analysis of compression ignition Engine operated on waste fried oil methyl esters. They performed a test on single cylinder, 4 stoke diesel engine direct injection diesel engine operated on methyl esters of waste fried oil blended with mineral diesel. They found that brake thermal efficiency of blend B50 (50% biodiesel + 50% mineral diesel) found 6.5% lower than that of diesel. For B50, brake specific consumption observed was 6.89% higher than that of diesel. CO emissions were reduced by 21–45% for different blends. The particulate matters were lower by 23–47%. Because of insignificant sulfur content, the sulfur dioxide emissions were lower by 50–100% for different blends [18].

C. T. Alves et al. in 2012 studied the production of biodiesel from waste frying oil with zinc aluminate ($ZnAl_2O_4$) as a heterogeneous catalyst, at temperatures between 60 and 200 ºC, in an alcohol : oil molar ratio of 40:1, 2 hour reaction time, stirring at 700 rpm and different catalyst amounts (from 1% to 10% based on oil weight). They characterized the Synthesised and recovered catalyst for their physical and textural properties. in Thermogravimetric analysis (TGA) and Differential scanning calorimetry (DSC) ,Powder X-ray diffraction (XRD) and The particle and pore sizes were measured by transmission electron microscopy (TEM).Residual glycerin and biodiesel were also observed in the recovered catalysts[19].

Jing Guo et al. in 2012 examines the composition and combustion performance of biodiesel produced from waste cooking oil.They prepared six fuel batches produced from waste oil and determine their physical and chemical properties. Furter they monitored exhaust emissions of two off-road engines for 5–100% biodiesel blends, and found reduced emissions of partial combustion products but a rise in Nox, which is max for between 5 and 20% biodiesel content [20].

Amin Talebian-Kiakalaieh et al. in 2013 performed transesterification of waste frying oil using Hetrogenous catalyst (heteropoly acid) with methanol. They investigated the relationship between process variable and free fatty acid conversion using Response surface methodology (RSM) and artificial neural network (ANN) and found highest conversion was 88.6 % at optimum condition being 14h reaction time, 65^0c reaction temperature, 70:1 methanol to oil molar ratio and 10 wt% catalyst load.

Conclusion

Number of researches, investigation and studies on current status of production, cost, global trend, economic viability of bio fuel and it has indicated that it offer excellent and efficient promises as an alternative fuel for compression ignition engine in its transportation sector also in energy sector. There are various bio-fuels and their characteristics and impacts has been studied and discussed and found to be an effective alternative fuel for compression ignition engine with different blending ratio. Main advantage is that it helps in improving the thermal efficiency of engine, reducing the brake specific energy consumption with some disadvantages like viscosity, political and production related issues.

Currently next generation bio-fuel is a promising bio-fuel but it is still under development and require extensive research and development (R&D) to overcome problems like scientific, economic, technical, and sustainability barrier. Next generation bio-fuels should have essential and efficient characteristics over conventional diesel fuel.

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