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Review: "Production of Biodiesel from Acid Oil"

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ABSTRACT

Energy is the basic unit for the creation and Life. This makes the input for the socio-economic development of a country. As the demand of energy is increasing day by day, it is essential for every country to opt for other sources of energy which are non-depleting and biodegradable. Among all the existing sources of energy, Renewable energy seems to be one of the most important energy sources. In which Bio-fuels are the main constituent of energy. As diesel engine is effective and efficient power generation machine and it dominates Indian agricultural Sector, Industry, and Transportation Sector etc. In order to accomplish the objectives of this study a literature review has been carried out to find the available concept and method from which Biodiesel can be obtain from acid oil. During the literature review section, it is found that very less work has been done on production of biodiesel from acid oil. Based on the literature review, production of biodiesel from acid oil is carried out using three different catalysts (PTSA, H2SO4 & MSA) to obtain optimal process for production.

Keywords: *- Energy, Development, Renewable energy, agricultural Sector, Transportation, Biodiesel*

I. INTRODUCTION

Energy is one of the most valuable and significant inputs for growth of all sectors including agricultural, industrial service and transport sectors. Energy being the centre stage of national & global economic development for several decades. The demand and destruction of energy sources, around the world is increasing exponentially, specifically petroleum-based energy. Petroleum derived fuels, actually, exceeds the demand of any other fuels or energy resources. The world consumption for petroleum and other liquid fuel will grow from 96 million barrels/day in 2007 to 107 million barrels/day in 2030. Under these growth assumptions, approximately half of the world's total resources would be exhausted by 2030. Also, as per many scenario studies, the world oil production would peak sometime between 2007 and 2030 [1]. Therefore, the future energy availability is a serious global difficulty. Another, major global concern is environmental degradation or climate change such as global warming. Global warming is related with the greenhouse gases which are mostly emitted from the combustion of petroleum fuels. In order to control the emissions of greenhouse gases, Kyoto Protocol targets to reduce the greenhouse gas emission by a collective average of 5% below 1990 level of respective countries. The Intergovernmental Panel on Climate Change (IPCC) concludes in the Climate Change 2007 that, because of global warming effect the global surface temperatures are likely to increase by 1.1°C to 6.4°C between 1990 and 2100 [2].

A. Energy Crisis

There is a realization throughout the world that the petroleum resources which are non renewable, are limited and are being consumed at an alarming rate. The growing demand for energy and gradual extinction of fossil fuels has lead to an energy crisis. Most of the power in industries and transportation is derived from oil and coal. Special mention is needed for automobiles where almost all of the fuels for combustion engine today are derived from petroleum, a nonrenewable source of energy, which is nearing its end at an unprecedented pace. The grave name of the energy problem was sharply brought into focus by the oil crisis of 1973. Since then, several price hikes have taken place, upsetting economy of most of the nation. The globe today uses about 147 trillion kWh of energy which is expected to rise in the coming future [1]. Figures 1.1 and 1.2 show the expected rise in the world consumption of energy up to 2030. A major chunk of this rise will be due to the developing countries, which are bound to grow by leaps and bounds.

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Figure 1.1: World Marketed Energy Consumption [1]

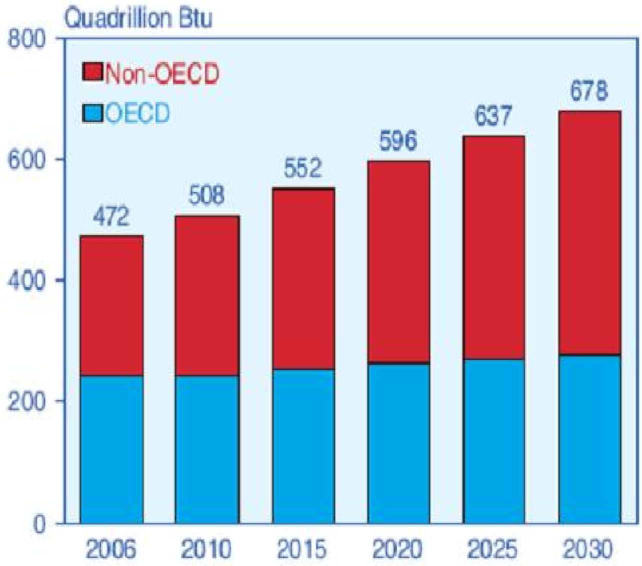

Fig 1.2: World Marketed Energy Use: OECD vs. Non-OECD [1]

Substantiates expectations regarding the rise of energy use, region wise.

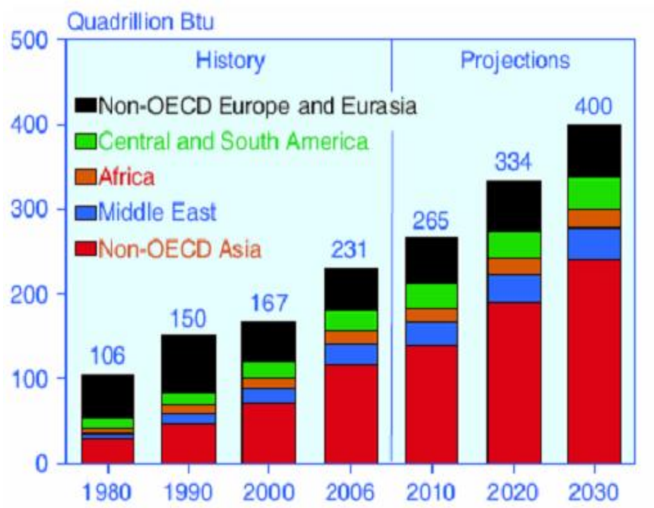

Figure 1.3 Marketed Energy Use by Region [1]

Hence, it can be seen that as a "Non-OECD" country, there is a need to develop energy solutions faster in India. Even in the "Non-OECD" countries, regional distribution shows that Asia is poised to grow the fastest in terms of energy use.

B. Energy Scenario: Indian Context

India had experienced robust growth for the past few years, and after an impressive 9.6 per cent Gross Domestic Product (GDP) growth in 2006-07 the Indian economy is headed towards 8.7 per cent growth in the current fiscal year [3]. The energy needs of India are also rising to cope up the growth rate. Of the 156.1 million tones of crude oil that India consumed in 2007-08, it produced only 34.12 million tones [4]. Indian economy is mainly agriculture based and modern agriculture system is heavily dependent upon internal combustion engines for running farm machinery, irrigation pump sets, and other equipments. Indian growth is mainly based on energy, produced by "oil-burning" in IC engines. It is very difficult to find clear blue sky in Indian metropolis. Petroleum fuels are major contributor to ecological imbalance in India. As Indian transportation, which has a key role in the development of economy, is heavily dependent upon diesel engines, it is not possible in any case to discard them. The renewable fuels must be sought to lease new life to existing engines in order to curb the twin problems of fuel scarcity and air pollution. Various national emission standards have been set by the Government of India through which the fleets are facing greater pressures to switch to cleaner alternative fuels. The alternative fuels are desirable from the fact that

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they are the only fuels used with recent engine developments, which can meet the stringent EURO-IV emission norms, which are expected to be enforced in India from 2011. India being richer in flora and fauna can look forward to use fuels from bio origin as the suitable alternatives. The prominent bio fuels from Indian perspective are ethanol and biodiesel. India, the world's second most populous nation, has seen its population exploding from 300 million in 1947 to around 1.2 billion today. This rapidly growing population has placed a strain not only on India's infrastructure, but also on its environment. According to the World Health Organization, New Delhi is one of the top ten most polluted cities in the world. Two primary sources of air pollution in India are vehicular emissions and untreated industrial smoke. The number of vehicles has registered a sharp increase more so, during the last decade. In Delhi alone, the vehicle number has crossed about 4.6 million. Today, the vehicular pollution contributes roughly 64 % of total air pollution in Delhi, followed closely by Mumbai at 52% and somewhat controlled fig of 30% for Kolkata. About 50% of the total petroleum products consumed in the country go into the transport sector mainly in the form of high-speed diesel and gasoline [5]. India's per capita energy use and carbon emissions, while lower than the world average, result in a substantial percentage of world energy use and carbon emissions, due to the country's large population and heavy reliance on fossil fuels. Increased use of renewable energy is one means of reducing carbon emissions.

C. Energy Demand and Supply

Energy Security is driven by the demand and supply behavior. India ranks sixth in the world in terms of energy demand accounting for 3.64% of world commercial energy demand in 2007. Although India ranks fifth in total energy consumption in the world (404.4 mote (million tones of oil equivalent), this is only 17.12% of the energy consumed by the largest consumer, i.e. USA (2361.4 mote). In per capita terms, its consumption is only about 20% of the global average. Rapid Industrialization and Globalization have pushed the demand of energy to new heights. In the year 2011, India will have a total population of about 1.3 billion people of which 68% will be living in rural areas. Since diesel constitutes 37 % of total petroleum consumption mainly for transportation and other purposes, its demand is integrally related to economic growth and is seen as a growth inducing factor. The stress of the over-burdening population will augment the strain in terms of the volume of fuel required, but the picture of proven oil reserves distribution doesn't reflect the pleasant sight at all. The share with respect to the energy distribution of the remaining oil reserves across the world is shown in Fig 1.4.

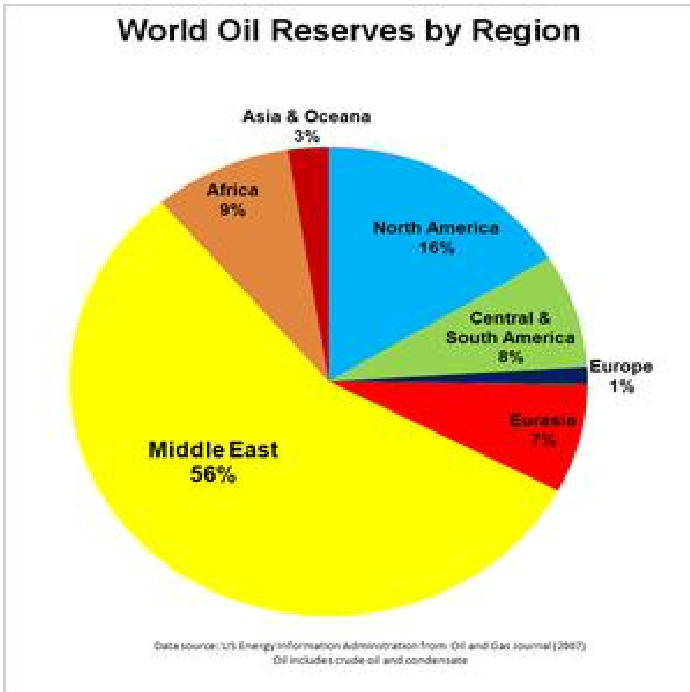

Fig 1.4: World Oil Reserves, 2010 [4]

It can be observed, that bulk of the reserves are with Middle East. The condition of the Asia Pacific countries presents a dismal trend, presently, only 3.3% of the total share is in their buckets. Therefore, it is apparent that the Asian countries have to change their fuel strategy or live with the escalating burdens of oil imports or with joint venture abroad with the hope to meet their requirement. At present, India imports about 77.94 % of its crude oil required. Net import of crude oil has increased from 74.10 MMT in 2000-01 to 121.67 MMT in 2007-08. India paid Rs.2, 72,699 cores for importing crude oil in 2007-08. This import comprised about 30 % of the total value of Indian imports in 2007-08 [4]. Heavy dependence on import of crude oil is a subject of serious concern. As per The World Energy out Look, India's dependence on oil import would grow to 91.6 % by the year 2020. The trend of import of crude oil in India is shown in Table 1.1.

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Table 1.1: Import of Crude Oil in India [4]

YEAR	CRUDE OIL	
	Qty MMT	Value (Rs. In Crores)
2000-01	74.10	65932
2001-02	78.70	60397
2002-03	85.81	62876
2003-04	90.43	83528
2004-05	95.86	117003
2005-06	99.41	171702
2006-07	110.86	219991
2007-08	121.67	272699
2008-09	132.78	348288
2009-10	159.26	375378

As already evident from above discussion that the self reliance of our country is declining and has reached to a very low fig of 21.86% in year 2007-08 as shown in Table 1.2. Although, India has invested considerable resources in petroleum sector, the crude oil production has stagnated around 32-33 million metric tones per year over the past decade. The majority of India's roughly 5.4 billion barrels in oil reserves are located in the Bombay High, Upper Assam, Cambay, Krishna-Godavari, and Cauvery basins. India's average oil production level for 2007 was 80, 1000 barrels per day [4]. But the consumption continues to outstrip production. Over the years, the domestic availability of the crude oil has not kept pace with the demand.

D. Diesel Engines

Before discussing the combustion characteristics of biodiesel, it would be relevant to discuss the basic concept of compression ignition engine or diesel engine. Compression ignition engine was invented by Rudolf Diesel, which is commonly known as diesel engine today. The engine cycle of the diesel engine is diesel cycle which is a modified Otto cycle and known as constant pressure cycle. The diesel engine relies on a high compression ratio, typically greater than 14:1 to initiate the combustion. This, higher compression ratio is in order to bring the air temperature to a level where auto ignition is promoted when the fuel is injected to the cylinder at the end of the compression stroke. A principal requirement of a fuel for diesel engine is that it must be auto ignited easily [5]. Diesel engines are usually classified into two categories; direct and indirect injection. Direct injection means the fuel is directly injected into the combustion chamber. The fuel is injected under high pressure through a nozzle with single or multiple tiny orifices. This results in a fuel spray with very fine droplets thus making it easier for the fuel to evaporate and burn. But, in the indirect injection engines, the fuel is injected into an auxiliary chamber that is adjacent and connected to the main combustion chamber. Most combustion start sooner in this chamber and burning gases exit the chamber with high velocities giving a greater ability for mixing of fuel and air. These types of engines are not very sensitive on the ignition ability of the fuels. Generally, the combustion process in diesel engines can be divided into four steps-

(1) Ignition delay: it is a period between the start of injection and the start of combustion.

(2) Ignition: it is taken place after ignition delay period.

(3) Initial combustion or premixed combustion phase: which occurs after ignition and it consumes about 5% to 10% of injected fuel.

(4) Diffusion controlled or mixing controlled phase of combustion: it occurs after premixed combustion and produce a high temperature and pressure in the combustion chamber. It consumes all of the remaining fuel [6].

During the ignition delay period many processes occur within the cylinder. Fuel has to be broken down into droplets, heated, vaporized, and mixed with air. Both physical and chemical delays are present and those two delays are not added since they are usually overlapping. Due to the high compression ratio the temperature and pressure of the air at the time of injection are normally well above those required to support chain-reaction in a uniform fuel-air mixture. Under these conditions, ignition of any element of the charge does not require transfer of energy from another portion but will occur when the local temperature, pressure, and mixing of fuel and air make combustion possible [7]. In general, the combustion of the fuel in the compression-ignition engine depend on the local condition in each part of the charge and does not depend

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on the spread of the flame through the charge like spark ignition engines. However, the local flame may assist the ignition of adjacent sections if the local conditions (e.g., fuel-air ratio) support combustion. Local flames may also reduce the reaction time of adjacent sections by raising their temperature and pressure. The combustion rate or heat release rate is thus a function of the state and distribution of the fuel as well as the pressure and temperature in the combustion chamber, where the latter is initially dictated by the compression ratio [8]. Other factors that influence the combustion process are injection timing, turbulence in the combustion chamber, engine revolution along with several other fuel properties such as cetane number, kinematic viscosity, and density and distillation temperature. The advantages of diesel engines are that it has greater efficiency, durability and good fuel economy compared to gasoline engines. Therefore, the application range of diesel engines is very wide. Most of the applications of diesel engines are in major transportation sector such as bus, truck, train and ship, and heavy machinery like construction equipments.

E. Need for Alternate Fuels

To solve dual problems of fossil fuel depletion and environmental degradation, the renewable fuels with lower environmental impact are necessary. Nowadays, many new fuels have been used and biomass derived fuels are among them. Some of the well known biomass derived fuels are ethanol for gasoline engines and bio-diesel for compression ignition engines. Biodiesel is a renewable and environmental friendly alternative fuel for diesel engine which is produced from variety of vegetable oils and animal fats by the trans-etherification process. Transesterification is a chemical reaction in which vegetable oils and animal fats are reacted with alcohol in the presence of a catalyst. The products of reaction are fatty acid alkyl ester and glycerin, and the fatty acid alkyl ester is known as biodiesel. Bio-diesel is an oxygenated fuel containing 10% to 11% oxygen by weight. Also it is a sulphur-free fuel. These lead biodiesel to more complete combustion and less harmful exhaust emissions. However, biodiesel fuel has higher viscosity, density, pour point, flash point and cetane number than diesel fuel. Also the energy content or net calorific value of biodiesel is about 12% lower than that of diesel fuel on a mass basis. Using biodiesel can help in reducing the world's dependence on fossil fuels and also has significant environmental benefits. Using biodiesel instead of the conventional diesel fuel reduces exhaust emissions such as the overall life circle carbon dioxide (CO_2), particulate matter (PM), carbon monoxide (CO), sulphur oxides (SO_x), volatile organic compounds (VOCs), and unburned hydrocarbons (UBHC). However, most of the biodiesels give 10% to 15% higher oxides of nitrogen (NO_x) when fuelling with 100% bio-diesel [9]. Depending on the abundantly availability of feedstock in local region, the different feedstock's are tried for the biodiesel production. In the United States, the primary sources for biodiesel production is soy bean oil, while EU nations prefer to utilize rapeseed oil, and in South East Asia regions, palm oil, coconut oil and Jatropha oil are used for biodiesel productions. Growing the production of biodiesel in many countries around the world has been accompanied by the development of standards to ensure high fuel quality. The biodiesel standards are ASTM D6751 in the United States and EN 14214 in EU Nations. The properties of biodiesel are mainly determined by the structure of fatty acids alkyl esters which constitutes it, particularly, the combustion characteristics such as ignition quality, and the fuel properties such as density, viscosity, pour point and oxidation stability of biodiesel are mostly affected by the structure of fatty acids alkyl esters [10].

F. Feedstock's for Biodiesel

A variety of oils can be used to produce biodiesel. These include:

- Virgin oil feedstock e.g. rapeseed and soybean oils are most commonly used in USA and EU.
- Waste vegetable oils (WVO), collected from fast food chain.
- Animal fats including tallow, lard, chicken fat and fish oil.
- Algae- It can be grown using waste materials such as sewage and without displacing land currently used for food production.
- Acid Oil.

As 80% of the price of biodiesel is attributed to feedstock cost, it shall be relevant to explore cheaper feedstocks for biodiesel production economically and acid oil seems to be most promising cheaper feedstock for biodiesel production. Acid Oil is made from soap stock which is a byproduct of edible oil refining process and available in bulk in India.

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II. LITERATURE REVIEW

Vegetable oils were used as fuel for diesel engines to some extent since the invention of the compression ignition engine by Rudolf Diesel in the late 1800`s. During the early stages of the diesel engine, strong interest was shown in the use of vegetable oils as fuel but this interest declined in the late 1950`s after the supply of petroleum products become abundant [11]. During the early 1970`s, oil shock, however, caused a renewed interest in vegetable oil fuels. This interest evolved after it became apparent that the world’s petroleum reserves were dwindling. At present, in order to replace a part of petroleum based diesel usage, the use of vegetable oils derived biodiesel has been starting in many countries. Vegetable oils are renewable energy source and significant environmental benefit can be derived from the combustion of vegetable oil based biodiesel rather than petroleum based diesel fuels. As vegetable oils contain only trace quantities of sulphur, therefore, the combustion of biodiesel emits 99% less Sox emission. Since prices of edible oils used for biodiesel production are quite high, efforts have been made to use cheaper feed stocks such as non edible plant oils, waste cooking oil and animal fat so that biodiesel could be produced at affordable price [12]. Acid oil seems to be a potential feedstock for biodiesel production. The research work embodied in this thesis aims to prepare biodiesel from high Free Fatty Acid (FFA) acid oil and to evaluate the performance and exhaust characteristics of a biodiesel/ diesel fuelled CI engine. The available literature on the subject matter of the thesis has been thoroughly reviewed and presented in this chapter. A review of current literature shows that among the various alternative fuels which could match the combustion features of diesel oil at a relative low oil price and which can be easily adopted for use in existing engine technologies without any major modification is vegetable oil derived fuel.

1. Biodiesel Production from High FFA Oil

As acid oil has high free fatty acid content, there is a need to neutralize the FFA. There are normally two routes of neutralization of FFA such as saponification of FFA and esterification of FFA using acid catalyst. After neutralization of FFA, the transesterification is carried out to convert triglycerides into mono alkyl esters. It is also seen that the major factors which affect the conversion efficiency of the both esterification and transesterification process are molar ratio of alcohol: oil, amount of catalyst, reaction temperature and reaction duration.

2. Esterification Reaction

Free fatty acids can be esterified by alcohols in the presence of suitable acidic catalyst as shown in Fig 2.1.

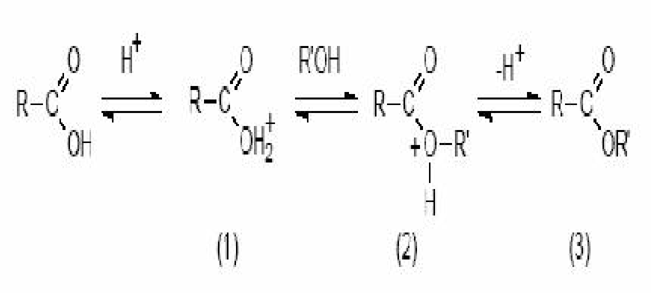

Fig 2.1: Mechanism of Acid Catalyzed Esterification Process [13]

Acid catalyzed esterification is preferred for oils having high free fatty acid content. The difficulty with alkaline-esterification of these oils is that they contain large amounts of free fatty acids (FFA). These free fatty acids quickly react with the alkaline catalyst to produce soaps that inhibit the separation of the ester and glycerin. A two-step process is developed to convert the high FFA oils to its mono- esters. The first step, acid catalyzed esterification reduces the FFA content of the oil to less than 2%. The second step, alkaline catalyzed transesterification process converts the products of the first step to its mono-esters and glycerol [14]. In an effort to increase utilization of fats and oils with high concentrations of FFA, acid catalysts were investigated at elevated temperatures to determine their efficacy under various operating conditions. Acid-catalyzed alcoholics of soybean oil using sulfuric, hydrochloric, formic, acetic, and nitric acids was evaluated at 0.1 and 1 wt% loadings at temperatures of 100 and 120°C in sealed ampoules, but only sulfuric acid was effective [15].Haas et al. used acid-catalyzed esterification for the synthesis of fatty acid methyl ester (FAME) from acid oil. Soybean acid oil contained 59.3 wt% FFA, 28.0 wt% TAG, 4.4 wt% DAG, and less than 1% MAG. Maximum esterification occurred at 65°C and 26 h reaction at a molar ratio of total fatty acid/methanol/sulfuric acid of 1:15:1.5 [16] .Naik et al. adopted the mechanism of a dual process for the production of biodiesel from Karanja oil containing FFA up to 20%. The first step is acid-catalyzed esterification by using 0.5% H_2SO_4, alcohol 6:1 molar ratio with respect to the high FFA Karanja oil to produce methyl ester by lowering the acid value, and the next step

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is alkali-catalyzed transesterification. The yield of biodiesel from high FFA Karanja oil by dual step process has been observed to be 96.6–97%.

3. Transesterification Process

Transesterification process is widely used in the production of biodiesel. In this reaction, fatty acids in vegetable oil are reacted with an alcohol in presence of a catalyst to form fatty acid alkyl ester. In fact, the transesterification can take place with or without a catalyst. Either an acid or alkali catalyst can be used in the transesterification to produce methyl, ethyl or butyl esters of fatty acids. In reaction, the stoichiometric ratio of alcohol to vegetable oil is 3:1 and the products are 3 mol of fatty acid alkyl ester and 1 mol of glycerol. Mostly, the molar ratio of alcohol to vegetable oil is determining the ester conversion rates. It has been reported by that, a molar ratio of 6:1 of alcohol to vegetable oil gives the ester conversion rate over 90%. One of the factor influences on ester conversion rate is the fatty acid composition of vegetable oils. Higher saturated fatty acid compositions in vegetable oils results difficulties in transesterification reaction and produces lower ester conversion rate. Among the alcohols; methanol, ethanol, propanol and butanol [17] are used for transesterification process but methanol and ethanol are preferred because of their lower cost, easy availability and physicochemical advantages. Methanol is further preferred to ethanol as it reacts faster in the medium and can be easily dehydrated as compared to ethanol. In case of methyl esters separation of glycerol is also faster with low stoichiometric ratio.Freedman et al. [18] studied the variables that affect the yield and purity of esters produced by transesterification process. The water content of all materials, including the catalyst and triglyceride, and the acid value of the triglyceride were required to be very low. Other important factors for transesterification are reaction time and temperature. The reaction temperature depends on the type of alcohol being used and was recommended to be a few degrees below the boiling point of the alcohols used. Noureddini et al.[19] found that increasing the reaction temperature from 30 to 70°C led to significant increases in the reaction rate with temperature up to 50°C, but little increase in reaction rate over 50 °C.Chen et al. [20] found that acid catalysts are considerably slower than base catalysts. Alkali metal alkoxides are the most effective transesterification catalyst compared to the acidic catalyst. Sodium alkoxides are among the most efficient catalysts used for this purpose, although KOH and NaOH can also be used. Though alkaline metal alkoxides are the most effective, they require absence of water which makes them appropriate for typical industrial processes. Alkaline metal hydroxides (KOH and NaOH) are cheaper than metal alkoxide, but less active. NaOH is cheaper but requires high temperature (70°C) while KOH reacts at room temperature and by-product (potassium sulphate) generated during reaction can be sold as a fertilizer [21].Allen et al. [24] reported that reaction times in the range 15-30 minutes were adequate for greater than 98% conversion when canola oil was transesterified with methanol at 60°C.The optimization of various parameters is necessary for maximizing the biodiesel yield during the transesterification process. Various researchers have made attempts to optimize the process parameters in their studies [22- 23].

4. Biodiesel as a diesel substitute

Presently, the well known method of biodiesel usage is its blending with conventional diesel fuel. The common ratio is 80% conventional diesel fuel to 20% biodiesel, which is also known as “B20”. The application of ester of vegetable oils as diesel engine fuels has been studied by several researchers.Peterson et al. [24] found that the engine performance of a diesel engine fuelled with methyl and ethyl esters of rapeseed oil was comparable to standard diesel fuel with the ester showing slightly lower power output and associated higher brake specific fuel consumption. The methyl ester was reported to produce slightly more power than the ethyl ester.Shaheed et al. [25] investigated the performance and exhaust emission evaluation of a small diesel engine fuelled with coconut oil methyl esters. They showed coconut oil methyl ester had comparative engine performance to diesel fuel and emission characteristics were equally as good as or better than diesel fuel for most of the exhaust constituents.Hamasaki et al. [26] investigated the potential suitability of waste vegetable oil methyl ester. They pointed out that the exhaust gas emissions from the waste vegetable oil methyl ester were acceptable and smoke emission was lower than that of the diesel fuel.Mittelbach et al. [27] found in their tests with methyl esters of frying oil that the level of NOx was high due to the high combustion temperature. This high temperature was attributed to the high oxygen content of the ester fuel. However, all other emissions, including polycyclic aromatic hydrocarbons (PAH), were low.Lapuerta et al. [28] collected and analyzed the body of work written

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mainly in scientific journals about diesel engine emissions when using biodiesel fuels as opposed to conventional diesel fuels. Since the basis for comparison is to maintain engine performance, the first section is dedicated to the effect of biodiesel fuel on engine power, fuel consumption and thermal efficiency. The highest consensus lies in an increase in fuel consumption in approximate proportion to the loss of heating value. In the subsequent sections, the engine emissions from biodiesel and diesel fuels are compared, paying special attention to the most concerning emissions: nitric oxides and particulate matter, the latter not only in mass and composition but also in size distributions. In this case the highest consensus was found in the sharp reduction in particulate emissions.Nabi et al. [29] investigated different parameters for the optimization of biodiesel production in the first phase of this study, while in the next phase of the study performance test of a diesel engine with neat diesel fuel and biodiesel mixtures were carried out. Biodiesel was made by the well known transesterification process. Cottonseed oil (CSO) was selected for biodiesel production. The transesterification results showed that with the variation of catalyst, methanol or ethanol, variation of biodiesel production was realized. A maximum of 77% biodiesel was produced with 20% methanol in presence of 0.5% sodium hydroxide. The engine experimental results showed that exhaust emissions including carbon monoxide (CO) particulate matter (PM) and smoke emissions were reduced for all biodiesel mixtures. However, a slight increase in oxides of nitrogen (NOx) emission was experienced for biodiesel mixtures.Utlu et al. [30] examined the usage of methyl ester obtained from waste frying oil. In this study, methyl ester was tested in a turbocharged, four cylinders and direct injection diesel engine. The results were compared with diesel fuel. Engine tests results obtained with the aim of comparison from the measures of torque, power; specific fuel consumptions are nearly the same. In addition, amount of emission such as CO, CO2, NOx, and smoke darkness of waste frying oils are less than diesel fuel.Godiganur et al. [31] used diesel, methyl ester of mahua oil and its blends in a Cummins 6BTA 5.9 G2- 1, 158 HP rated power, turbocharged, DI, water cooled diesel engine at constant speed of 1500 rpm under variable load conditions.The volumetric blending ratios of biodiesel with conventional diesel fuel were set at 0, 20, 40, 60, and 100. Engine performance (brake specific fuel consumption, brake specific energy consumption, thermal efficiency and exhaust gas temperature) and emissions (CO, HC and NOx) were measured to evaluate and compute the behaviour of the diesel engine running on biodiesel. The results indicate that with the increase of biodiesel in the blends CO, HC reduces significantly, fuel consumption and NOx emission of biodiesel increases slightly compared with diesel. Brake specific energy consumption decreases and thermal efficiency of engine slightly increases when operating on 20% biodiesel than that operating on diesel.

Baiju et al. [32] investigated the suitability of methyl and ethyl ester from Karanja oil as an alternative diesel fuel. The methyl and ethyl esters of Karanja oil were prepared by transesterification using both methanol and ethanol. The physical and chemical properties of ethyl esters were comparable with that of methyl esters. However, viscosity of ethyl esters was slightly higher than that of methyl esters. Cold flow properties of ethyl esters were better than those of methyl esters. Performance and exhaust emission characteristics of the engine were determined using petro diesel as the baseline fuel and several blends of diesel and biodiesel as test fuels. Results show that methyl esters produced slightly higher power than ethyl esters. Exhaust emissions of both esters were almost identical. These studies show that both methyl and ethyl esters of Karanja oil can be used as a fuel in compression ignition engine without any engine modification.

III. CONCLUSION FROM LITERATURE REVIEW

The following salient observations are made from the literature review:

- There is a definite scope of research to use alternate fuels effectively to drive I.C. engines in order to conserve the fossil fuel for a longer period.
- Alternate fuels derived from bio-oils are used either as SVOs or transesterified SVOs (known as biodiesels) – both are CO_2 neutral.
- Out of available technologies to power IC engines, the performance with biodiesels derived from non-edible vegetable oils come closer to that of present day engines with or without engine modifications (*preferable*).
- Biodiesels are advantageous over SVOs – lesser viscosity, better injection properties and combustion, higher CN, less HC & CO emissions, etc.
- However, they have higher NOx emissions due to the availability of O_2 (~10%) in fuel and higher combustion temperature.
- The NOx emission is 296 times more powerful greenhouse gas than CO_2 – not much work has been

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found on NOx reduction.All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

References

[1] International Energy Outlook 2009 by Energy Information administration, Office of Integrated Analysis and Forecasting, U.S. Department of Energy.

[2] IPCC Fourth Assessment Report: Climate Change 2007 by Intergovernmental Panel on Climate Change (IPCC).

[3] Economic Survey 2008.

[4] Ministry of Petroleum and Natural gas, Gov-t of India www.petroleum.nic.in./ petstat.pdf.

[5] Internal Combustion Engine by C. R. Ferguson.

[6] Technical Review of Diesel Fuels. By Chevron Products Company, 1998.

[7] C. F. Taylor; the Internal Combustion Engine in Theory and Practice Thermodynamic, Fluid Flow, Performance, Vol.1, 1985.

[8] C. F. Taylor; the Internal Combustion Engine in Theory and Practice Combustion, Material Design,Vol. 2. 1985.

[9] Jon H Van Gerpen, Charles L. Peterson, Goering E. Carroll; Biodiesel: An Alternative Fuel for Compression Ignition Engines. American Society of Agriculture and Biological Engineers. Distinguished Lecture Series No. 31,

[10] G. Knothe; Dependence of Biodiesel Fuel Properties on the Structure of Fatty Acid Alkyl Ester; Fuel Processing Technology, Vol. 86. Pp.1059– 1070, 2005.

[11] . Knothe; Cetane numbers-The History of Vegetable Oil-based Diesel Fuels. The Biodiesel Handbook. American Oil Chemist's Society Press, 2005.

[12] N. Usta, E. Ozturk, O.Can, E.S. Conkur, S.Nas, A.H. Con, A. C. Can and M.Topcu, Combustion of biodiesel fuel produced from hazelnut soapstock/waste sunflower oil mixture in a Diesel engine; Energy Conversion and Management, Vol. 46, pp.741-755, 2005.

[13] W. W. Christie; Preparation of ester derivatives of fatty acids for chromatographic analysis; Advances in Lipid Methodology – II, pp. 69-111, 1993.

[14] A.S. Ramadhas, S. Jayaraj and C. Muraleedharan; Biodiesel production from high FFA rubber seed oil; Fuel, Vol. 84, Issue 4, Pages 335-340, 2005.

[15] Michael J. Goff, Nicholas S. Bauer, Shailesh Lopes, William R. Sutterlinand and Galen J. Suppes; Acid-catalyzed alcoholysis of soybean oil, Volume 81, pp.415-420, 2006.

[16] Michael J. Haas, Paul J. Michalski, Stan Runyon, Alberto Nunez and Karen M. Scott; Production of FAME from acid oil, a by-product of vegetable oil refining; Vol. 80, pp. 97-102, 2003.

[17] X. Lang, A. K. Dalai, N. N. Bakshi, M.J.Reaney and P.B. Hertz; Progress on Energy and Combustion Science; Vol.31, pp. 466-487; 2005.

[18] B. Freedman, E. H. Pryde and W. F. Kwolek; Variables Affecting the Yields of Fatty Acids from Transesterified Oil; JAOCS; Vol. 61, pp.1638-1642,2007.

[19] H. Noureddini and D. Zhu; Kinetic of Transesterification of Soybean Oil; JAOCS, Vol. 74, pp. 1457-1463, 1997.

[20] H. Chen, Y Kubo, T Hoshi S. H. Heinemann, S Siler-Marinkovic and A.Tomasevic; Transesterification of sunflower oil in situ; Fuel, Vol. 77(12), pp.1389-1391; 1998.

[21] L. C. Meher, S. S. Dharmagadda and S.N. Naik; Optimization of alkali catalyzed transesterification of Pongamia pinnata oil for production of biodiesel; Bioresource Technology, Vol.97, Issue 12, pp. 1392-1397, 2006.

[22] C. A. W. Allen and K. C. Watts; A Batch Type transesterification unit for Biodiesel Fuels; CSAE paper 96404. CSAE, Saskatoon, SK.

[23] G. Antolin, F.V. Tinaut, Y. Briceno, V. Castano, C. perez and A.I. Ramrez; Optimization of biodiesel production by sunflower oil transesterification ; Bioresources technology, Vol.83, pp. 111- 114,2002.

[24]C. L.Peterson, D. L. Reece, R. Cruz and J.Thompson; A Comparison of Methyl and Ethyl Esters of Vegetable Oils as Diesel Fuel Substitutes; Proceeding of Alternative Energy Conference, ASAE, 1992.

[25] A. Shaheed, and E. Swain; Performance and Exhaust Emission Evaluation of a Small Diesel Engine Fuelled with Coconut Oil Methyl Esters; SAE Paper no. 981156, 1998.

ISSN 2395-3594

[26] K. Hamasaki, H.Tajima, K. Takasaki, K. Satohira, M. Enomoto and H. Egawa; Utilization of Waste Vegetable Oil for Diesel Fuel; SAE paper no. 2001-01-2021, 2001
[27] M. Mittelbach, and P. Trillhart; Diesel Fuels Derived from Vegetable Oils, Emission Test Using Methyl Esters of Used Frying Oil; JAOCS, Vol 65(10), pp. 1185-1190.
[28] Magin Lapuerta, Octavio Armas and J.R. Fernandez; Effect of biodiesel fuels on diesel engine emissions; Progress in Energy and Combustion, Vol. 34 pp. 198–223, 2008.
[29] Md. Nurun Nabi, Md. Mustafizur Rahman and Md. Shamim Akhter; Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions; Applied Thermal Engineering, Vol. 29, pp.2265–2270, 2009
[30] Zafer Utlu and M.Surreya kocak; The effect of biodiesel fuel obtained from waste frying oil on direct injection diesel engine performance and exhaust emissions; Renewable Energy, Vol. 33, pp.1936–1941, 2008
[31] Sharanappa Godiganur, C.H. Suryanarayana Murthy and Rana Prathap Reddy; Cummins engine performance and emission tests using methyl ester mahua (Madhuca indica) oil/diesel blends; Renewable Energy, Volume 34, Issue 10, pp. 2172–2176, 2009.

ISSN 2395-3594