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PRODUCTION OF BIODIESEL: INDUSTRIAL, ECONOMIC AND ENERGY ASPECTS : A REVIEW

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Abstract

Biofuels are fuels produced from hydrocarbon rich living organisms such as plants or microalgae by thermal chemical or biochemical conversion process. Biofuels such as biodiesel, biogas and syngas are combusted to generate energy. Biodiesel is an ecofriendly and an alternate of renewable diesel fuel. It is defined as an alternative fuel for diesel engines produced by chemically reacting a vegetable oil or animal fat with an alcohol such as methanol or mono-alkyl esters of long chain fatty acids derived from a renewable lipid feed stock. It is typically produced by reacting the fatty acids with alcohol in the presence of catalyst to produce the desired mono-alkyl esters and glycerol. After reaction, the glycerol, catalyst, and any remaining alcohol or fatty acids are removed from the mixture. The alcohol used in the reaction is typically methanol, although ethanol and higher alcohols have been used also. The majority of the biodiesel currently produced is made from soybean oil and this soya biodiesel consists of the five methyl esters. While neat (*i.e.*, 100%) biodiesel can be used, a blend of between 2 and 20% (by volume) of biodiesel with petro-diesel fuel is recommended to avoid engine-compatibility problems. With a flash point of 160°C, it is classified as non-flammable, biodegradable and non-toxic fuel. Biodiesel has emits much lower emissions than petro diesel and it can also be mixed with petro diesel to reduce emissions. For example B20 is a fuel containing 20% biodiesel and 80% petro diesel. Pure biodiesel is B100. Biodiesel reduces carbon dioxide emissions by 78%, and carbon monoxide emissions by 50%. It also does not have sulphur emissions. The purpose of this work is to study the development of biodiesel process at pilot plant scale using plant origin oil as the raw material with methanol and sodium hydroxide as the catalyst and evaluate the produced biodiesel as a fuel. It may lead to a revolutionary transformation of the current economic and energy scenario with an era of economic bloom and prosperity for our society.

Key words: Jatropha seeds, Soxhlet, transesterification, Biofuel, isolation and purification.

Introduction

The process to obtain fuel from a fat is not a new process. It was as early as 1853, when scientists E. Duffy and J. Patrick conducted the first Trans-esterification of a vegetable oil, many years before the first diesel engine became fully functional.

The first biodiesel-powered vehicle was Rudolf Diesel's prime model, a single 10 feet iron cylinder with a flywheel at its base, that run with this fuel for the first time in Augsburg, Germany on August 10, 1893, later he demonstrated his engine powered by peanut oil, a biofuel receiving the "Grand Prix" at the World Fair in Paris, France in 1900. Rudolf Diesel's believed that the utilization of a biomass fuel was the future of his engine, as he stated in his 1912 speech saying "the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time."

However during the 1920's, diesel engine manufacturers decided to alter their engines utilizing the lower viscosity of the fossil fuel, best known as petro diesel, rather than such biomass vegetable oil fuel. All petroleum industries were able to make inroads in fuel markets because their fuel was much, much cheaper to produce than the biomass alternatives, ignoring that years ahead it would bring high pollution costs. Around the 1940s, petroleum based products launched advertisements and the commitment of lower prices. They soon become the number one source of fuel.

A near elimination of the biomass fuel production infrastructure was for many years the result of petro diesel commercialization. Vegetable oil powered heavy

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duty vehicles in South Africa before World War II and Later, from 1978 to 1996, the U.S. National Renewable Energy Laboratory experimented with using algae as a biodiesel source in the "Aquatic Species Program". In the 1990's, France launched the local production of biodiesel fuel, known locally as di-ester, obtained by the transesterification of rapeseed oil.

Plant	Latin Name	lb. oil/ acre	Kg. oil/ hectare
Oil palm	*Elaeis guineensis*	4,585	5,000
Coconut	*Cocos nucifera*	2,070	2,260
Jatropha	*Jatropha curcas*	1,460	1,590
Rapeseed	*Brassica napus*	915	1,000
Peanut	*Arachis hypogaea*	815	890
Sunflower	*Helanthus annus*	720	800
Safflower	*Carthamus tintorius*	605	655
Soya bean	*Glycine max*	345	375
Hemp	*Cannabis sativa*	280	305
Corn	*Zea mays*	135	145

Note: Production average for ten common oil crops.

Today, environmental impact concerns and a decreasing cost differential made biomass fuels, such as biodiesel a growing alternative and, in remembrance of Rudolf Diesel first German who used biodiesel as fuel in diesel engine, August 10 has been declared International Biodiesel Day.

Pipette, electronic balance, separating funnel, magnetic stirrer, oven, thermometer, conical and round bottom flask, jatropha oil, soxhlet, measuring cylinder, NaOH, KOH, CH_3OH, H_2SO_4.

First the oil was extracted from the jatropha plant by mechanical method. The oil was purified by removing the fatty acids and by transestrification. Biodiesel produced by trans-esterification reaction can be catalyzed with alkali, acid or enzyme (Fig. 1.) Chemical catalyst processes, including alkali and acid ones are more practical compared with the enzymatic method. The complete schematic production of biodiesel is represented in Fig. 2.

Current status of Bio-diesel in Research and Development:

International Status:

The research work on utilization of bio-diesel started as early as 1970 in Brazil. The work was taken up as to procure an alternative fuel for diesel, which was in scares to Brazilians in the Second World War. Today Brazil is reaching to self-sufficiency in the petroleum.

Besides Brazil, Canada, U.S., Germany and many European countries have started working on this project as an alternative fuel of diesel. Many countries in Europe and America are working on above project in order to obtain the best result in extraction of biodiesel.

National Status:

In India the research is going on at various Institutes such as IIT, Delhi, Forest departments in various states of India. Various Agricultural Universities such as *Hissar University* (Haryana), Pant Nagar University (Uttrakhand) and also at Indian Institute of Petroleum-CSIR-(IIP) Dehradun, where first car run on Biodiesel.

In India the climatic conditions are very much suitable for the growth of *Jatropha curcas* L. At the same time the availability of manual labor and the Agro based economy of the country also exist, which can make this project viable. It helps not only in a way of being an alternative source of diesel for which we spend thousands of crores in foreign exchange but also it would became an alternative cash crop in many parts of the country thus giving boost to the Agro rural economy. In respect of forest conservation it would help in converting barren land under Green cover and help in environment conservation and maintaining the green cover over the Earth to an extent of 33% as prescribed. The agriculture sector of the country is completely dependent on diesel for its motive power and to some extent for stationary power application. Many alternative fuels like biogas, methanol, ethanol and vegetable oils have been evaluated as a partial or complete substitute to diesel fuel. The vegetable oil directly can be used in diesel engine as a fuel, because their calorific value is almost 90-95% of the diesel.

Types of bio-diesel:

Generally Biodiesel is produced from edible oil and non-edible oil. Biodiesel has been gaining worldwide popularity as an alternative energy source because it is non toxic, biodegradable and non flammable. Various edible and no edible oils, like rice bran oil, coconut oil, Jatropha curcas, castor oil, cotton seed

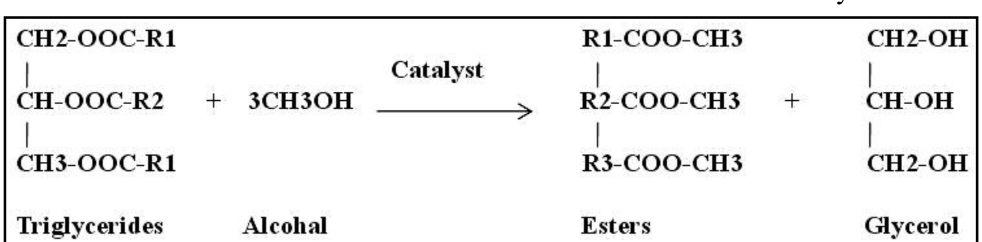

Figure 1. Transesterification reaction (Ma and Hanna, 1999).

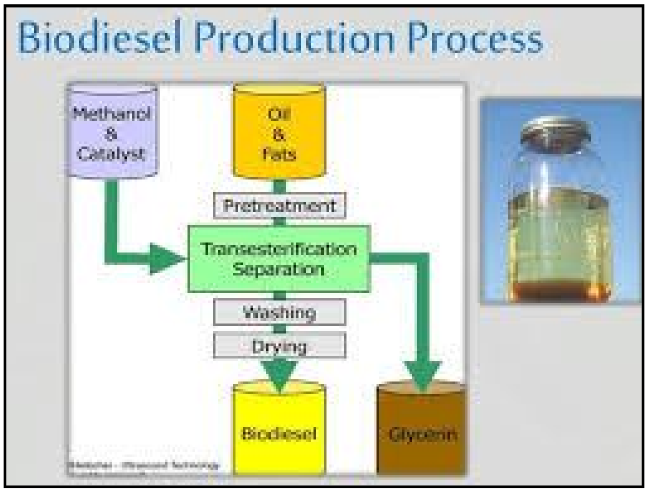

Fig. 2: A schematic diagram for the biodiesel production

oil, mahua, karanja which are either surplus and are nonedible type can be used for preparation of biodiesel. It may lead to a revolutionary transformation of the current economic & energy scenario with an era of economic bloom & prosperity for our society.

Rapeseed Biodiesel:

Rapeseed biodiesel is the preferred stock for the manufacture of biodiesel fuel in most of Europe due to its higher efficiency and greater yields over other alternatives like soybeans. According to William H. Kemp, author of "Biodiesel Basics and Beyond," there is some controversy over the use of rapeseed oil to make biodiesel because of the amount of nitrogen fertilizers required to mature the plants. This results in the release of a powerful greenhouse gas into the atmosphere, N_2O, which is a magnitude stronger than simple carbon dioxide.

Algae Biodiesel:

Algae are a high-yield source for biodiesel generation, but one of the biggest hurdles facing its development is economic viability (Scott *et al.,* 2010). Algae fuel, algal biofuel, or algal oil is an alternative to liquid fossil fuels that uses algae as its source of energy-rich oils. Also, algae fuels are an alternative to commonly known biofuel sources, such as corn and sugarcane (Darzins *et al.,* 2010). When made from seaweed (macroalgae) it can be known as seaweed fuel or seaweed oil. According to Ayhan Demirbas (2009) and Muhammet Fatih Demirbas (2011), authors of the book "Algae Energy," there is considerable debate as to how to profitably farm algae to manufacture biodiesel fuel. The process of turning algae into oil is among the best because algae can convert up to 60% of their mass into usable oil, which means more fuel can theoretically be made per square foot of space used over that of traditional crops (Oncel, 2013). However, in order for algae to truly become an alternative source of energy, cheaper and more efficient processes must be developed. Like fossil fuel, algae fuel releases CO_2 when burnt, but unlike fossil fuel, algae fuel and other biofuels only release CO_2 recently removed from the atmosphere via photosynthesis as the algae or plant grew. The energy crisis and the world food crisis have ignited interest in algaculture (farming algae) for making biodiesel and other biofuels using land unsuitable for agriculture (Yang *et al.,* 2010 and Cornell *et al.,* 2008). Among algal fuels' attractive characteristics are that they can be grown with minimal impact on fresh water resources, can be produced using saline and wastewater, have a high flash point, https://en.wikipedia.org/wiki/Algae_fuel - cite_note-6 and are biodegradable and relatively harmless to the environment if spilled. Algae cost more per unit mass than other second-generation biofuel crops due to high capital and operating costs, but are claimed to yield between 10 and 100 times more fuel per unit area (Carriquiry *et al.,* 2011 and Greenwell *et al.,* 2009).

S.No.	Microalgae	Oil Content (% dry weight)
1	*Schizochytrium sp.*	50-77
2	*Nitzschia sp.*	45-47
3	*Botryococcus braunii*	25-75
4	*Chlorella sp.*	28-32
5	*Cylindrotheca sp.*	16-37
6	*Phaeodactylum tricornutum*	20-30
7	*Crypthecodinium cohnii*	20
8	*Tetraselmis suecia*	15-23

Biodiesel from plants:

Palm, palm kernel and coconut oil are edible oils that can be extracted from the fruits of palm trees. Palm is one of the most controversial sources for biodiesel fuel because it is also edible oil. According to Julien Cribb, author of "The Coming Famine," proponents of using palm oil for biodiesel argue that the vast amount of monoculture palm farms currently in existence can simultaneously meet the world-wide demand for both biodiesel fuel and food, but as the human population grows the demand for fuel and food will both increase, and many feel that huge monoculture farming operations are too ecologically detrimental to rely on. Vegetable oils were proposed as diesel fuels as they are widely available from a variety of sources and they are renewable (Boehman, 2005). On the other hand, they were found to be problematic due to their greater viscosity which affecting piston, injector deposits and oil thickening (Baldwin, *et al.,* 1982, Peterson, *et al.,* 1983). Castor oil is viscous, pale yellow non-volatile and non-drying oil with a bland taste and is sometimes used as a purgative. It has a slight characteristic odour while the crude oil tastes slightly acrid with a nauseating after-taste. Relative to other vegetable oils, it has a good shelf life and it does not turn rancid unless subjected to excessive heat.

Jatropha curcas L. is a plant belonging to Euphorbiaceae family that produces a significant amount of oil from its seeds. Its fruit was shown in fig. 3. This is a non-edible oil-bearing plant widespread in arid, semi-arid and tropical regions of the world. The oil content in jatropha seed is reported to be in the ranges from 30 to 50% by weight of the seed. The jatropha tree has several beneficial properties such as its stem is being used as a natural tooth paste and brush, latex from stem is being used as natural pesticides and wound healing, its leaf as feed for silkworms among other uses (Chhetri, *et al.,* 2007a). It is a rapidly growing tree and easily propagated. Jatropha usually grows below 1400 meters of elevation from sea level and requires a minimum rainfall of 250mm, with an optimum rainfall between 900-1200mm (Bosswell *et al.,* 2003). This plant is not even browsed by animals for its leaves. Recently *J. curcas* is being considered as one of the most promising potential oil source to produce biodiesel in Asia, Europe and Africa. Chhetri *et al.,* (2007) elsewhere discussed the multiple use of jatropha for different purposes. Among other parts of the jatropha tree, the seed has so far been found appropriate for numerous uses.

Several studies have shown that there exists an immense potential for the production of plant based oil to produce biodiesel. Azam *et al.,* (2005) studied the prospects of fatty acid methyl esters (FAME) of some 26 non-traditional plant seed oils including jatropha to use as potential biodiesel in India. Among them. *Azadirachta indica*, *Calophyllum inophyllum*, *J. curcas* and *Pongamia pinnata* were found most suitable for use as biodiesel and they meet the major specification of biodiesel for use in diesel engine. Moreover, they reported that 75 oil bearing plants contain 30% or more oil in their seed, fruit or nut. Subramanian et al. reported that there are over 300 different species of trees which produce oil bearing seeds. Thus, there is a significant potential for non-edible oil source from different plants for biodiesel production as an alternative to petrodiesel.

Fig. 3: Jatropha plant with fruits

Common Water Hyacinth, or *Eichhornia crassipes* as its binomial name, is a free floating aquatic plant. It has thick, wide, waxy leaves and bright purple-blue flowers arranged in spikes as shown in Fig. 4 The plant is native to South America in the Amazon River Basin and is now the most widely distributed species in the world, after being introduced as an ornamental plant to different nations (Villamagna *et al.,* 2010). As a highly aggressive and invasive species, it propagates rapidly and has suffocated several lakes, rivers, and waterways. Water hyacinth (*Eichhornia crassipes*) represents a promising source for biofuel production and other bioactive compounds because of their high availability and high biomass yield (Malik, 2007). Water hyacinth samples showed variable lipid contents (6.79–10.45%), which by transesterification produced biodiesels (3.22–6.36%) and sediment (pigments + glycerol). Biodiesel composed either totally of saturated fatty acids (Myristic acid) of winter and autumn samples (Chochalow *et al.,* 1973).

Fig. 4: Water hyacinth plant

However, Myristic and Stearic acids are present with small proportion of pentadecanoic acid of summer and spring samples by 8.1% and 7.9% respectively. The monounsaturated fatty acid, oleic, was only recorded in the summer sample by 11.6%. So biodiesels produced from water hyacinth have good stability and acceptability to be used in diesel engines. The co-products (sediment) composed of pigments and glycerol reached to 4.69 mg/g and 1.05 mmol/L respectively in winter season. It has been found that pretreatment of water hyacinth by acid under mild conditions was found to be effective with high yield of fermentable sugars and production of ethanol. Sugars undergoes the fermentation process to give ethanol. About 430.66 milligrams of reducing sugars was obtained from per gram of dried, grounded water hyacinth, which resulted in an ethanol production rate of 1.40 g/L from a solution consisting of 20 g/L of glucose, 20 g/L of enzyme, and 20 g/L of yeast. This would mean that 1 gram of dehydrated water hyacinth can release around 852kJ of energy. This is a very improved method of enhancing bioethanol production from water hyacinth (Das, 2016 and Zhang, 2018).

Advantages of Biodiesel:

The use of alternative fuels in order to reduce the environmental impacts of diesel emissions has been extensively investigated (Hossain *et al.,* 2009a). Biodiesel is the only alternative fuels that can run in any conventional unmodified diesel engine. It can be stared anywhere that petroleum diesel fuel is used. The higher cetane number of biodiesel compared to petro-diesel indicates potential for higher engine performance. Tests have shown that Biodiesel has similar or better fuel consumption, horsepower, and torque and haulage rates as conventional diesel. The superior lubricating properties of biodiesel increases functional engine efficiency. Their higher flash point makes them safer to store. The biodiesel molecules are simple hydrocarbons chains, containing no sulphur, or aromatic substances associated with fossil fuels. They contain higher amount oxygen (up to 10%) that ensures more complete combustion of hydrocarbons. Biodiesel almost completely eliminates life cycle carbon dioxide emission. When compared to petro-diesel it reduces emissions of particulate matter by 40%, unburned hydrocarbons by 67%, carbon mono oxide by 44%, sulphates by 100%, polycyclic aromatic hydrocarbons (PAHs) by 70%, and the carcinogenic nitrated PAHs by 90% on an average. Biodiesel works like petro-diesel and gasoline it is a fuel to run transportation vehicles. The byproduct glycerol has great applications in the pharmaceutical, food and plastics industries.

The role of biodiesel:

Biodiesel Vs diesel:

It is well-known that the hydrocarbons in the diesel fuels include a diversity of paraffins, olefins, naphthalenes and aromatics (Srivastava, 2000). Therefore, carbon numbers of these hydrocarbons present in the diesel fuels are mostly in the ranges of 12–22. Due to its high energy conversion and power output in diesel engines, diesel fuel have been extensively used in heavy truck, city transport bus, electric generator, farm equipment, etc. Biodiesel, one of green fuels and or clean energies, is compatible with traditional petroleum-based diesel and both can be completely blended without any stratification. From the viewpoint of their chemical composition and properties of biodiesel fuels and petro-diesel are as follows.

Overall Ozone:

Overall ozone (smog) forming potential of biodiesel is less than diesel fuel. The ozone forming potential of specified hydrocarbon was nearly 50% less than measured for biodiesel.

Sulphur Emission:

Sulphur emission. is essentially eliminated with pure biodiesel. The exhaust emission of sulphur oxides and sulphates (major component of acid rain) from biodiesel were essentially eliminated compared to sulphur and sulphates from biodiesel.

Criteria Pollutants:

C.P. is reduced with biodiesel use. The use of biodiesel is an unmodified diesel engine resulted in substantial reductions of unburned hydrocarbon, carbon mono oxide and particulates matter. Emission nitrogen oxide is slightly increased.

Carbon Mono Oxide and Hydrocarbons:

The exhaust emission of carbon mono oxide (a poisonous gas) from biodiesel was 50% lower than emission from diesel. Hydrocarbon the exhaust emission of total hydrocarbon (a contributing factor in the localized formation of smog and ozone) were 93% lower for biodiesel than diesel.

Nitrogen Oxides:

NO_X emission from biodiesel increase or decrease depending on the engine family and testing procedure. Nitrogen oxides emission (a contributing factor in the localized formation of smog and ozone) from pure biodiesel increased in this test by 13%. However, biodiesels lack of sulphur allows the use of NOX control technologies that cannot be used with conventional diesel. So biodiesel NOX emission can be effectively managed and efficiently eliminated as a concern of the fuel's use.

Major negative aspects attributed to use of biodiesel includes:

High cost of production:

This will eventually solve itself when large scale production and use starts. Also, the price of petro diesel does not take into account its actual cost; the US General Accounting Office estimated that the true cost for a barrel of crude oil to the US citizen is more than USD 48.

Modifications are required to the Automobiles for use of biofueles:

Many automobiles brands are currently marketed ready for use of bio diesel. More information could be obtained from the manufacturers themselves.

High CFPP (Cold Filter Plugging Point) values:

CFPP values and hence solidification and clogging of the system at low temperatures. This problem occurs only in places where the temperature goes down to 0^oC, even here the problem is currently solved by adding additives.

Properties of biodiesel:

A general understanding of the various properties of biodiesel is essential to study their implications in engine use, storage, handling and safety.

Density / Specific gravity:

Biodiesel is slightly heavier than conventional diesel fuel. This allows use of splash blending by adding biodiesel on top of diesel fuel for making biodiesel blends. Biodiesel should always be blended at the top of diesel fuel. If biodiesel is first put at the bottom and then diesel fuel is added, it will not mix.

Cetane number:

Cetane number of a diesel engine fuel is indicative of its ignition characteristics. Higher the cetane number, better it is in its ignition properties. Cetane number affects a number of engine performance parameters like combustion, stability, drive ability, white smoke, noise and emission of CO and HC. Biodiesel has higher cetane number than conventional diesel. This results in higher combustion efficiency and some other combustion.

Viscosity:

In addition of lubrication of fuel injection system components, fuel viscosity controls the characteristics of the injection from the diesel injector (droplets size, spray characteristics etc.). The viscosity of methyl ester can go to very high levels and hence, it is important to control it with in an acceptable level to avoid negative impact on fuel injection system performance. Therefore, the viscosity specifications proposed are same as that of the diesel fuel.

Flash Point:

Flash point of a fuel is defined as the temperature of which it will ignite when exposed to a flame or spark. The flash point of a biodiesel is higher than the petroleum based diesel fuel. Flash point of biodiesel blends is dependent on the flash point of the base diesel fuel used, and increase with percentage of biodiesel in the blend. Thus in storage, biodiesel and its blends are safer than conventional diesel. Residual alcohol in the biodiesel reduces its flash point directly and its harmful to fuel pump, seals, elastomers etc. also reduces the combustion quality.

Pour Point:

Normally either pour point or CFPP are specified for biodiesel. French and Italian biodiesel specification specify pour point where as other specify CFPP. Since CFPP reflects more, accurately the cold weather operation of fuel, it is proposed not to specify pour point for biodiesel. Pour point depressants commonly used for diesel fuel do not work for biodiesel.

Cloud Point:

Cloud point is the temperature at which a cloud or haze of crystals appear in the fuel under test condition and thus becomes important for low temperature operations. Biodiesel generally has higher cloud point than diesel fuel.

Free and total glycerol:

The degree of conversion completeness of the vegetable oil is indicated by the amount of free and total glycerol present in the bio diesel. If the actual number is higher than specific values, engine fouling, filter clogging etc. can occur. Manufacturing process controls are necessary to ensure low free and total glycerin. Free glycerol if present can build up at the bottom of the storage and vehicle fuel tanks.

Sulphur Contents:

Biodiesel generally contain less than 15-ppm sulphur. ASTM D 5453 test is suitable test for such low level of sulphur. ASTM D 2622 used for sulphur determination of diesel fuels gives falsely high results when used for biodiesel. More work need to done to assess suitability of ASTM D 2622 application to B20 biodiesel blend. The increase in oxygen content of the fuel affects precision of this test method.

Water Content:

Biodiesel and its blends are susceptible to growing microbes when water is present in fuel. The solvency properties of the biodiesel can cause microbial slime to detach and clog fuel filters.

Methanol/Ethanol Content:

High levels of free alcohol in biodiesel cause accelerated deterioration of natural rubber seals and gaskets. Damage to fuel pumps and injectors which have natural rubber diaphragms has been very common types of failure methanol is membrane permeable and can cause nerve damage. Therefore, control of alcohol content is required.

Industrial and commercial uses:

The use of biodiesel has drawn attention in the last decade as it is a renewable, biodegradable, and nontoxic fuel, and has been industrially produced from vegetable oils in North America and Europe and from waste edible oils in Japan and Malaysia (Shimada, *et al.,* 1999, Hossain *et al.,* 2009b). Oil seed rape (*Brassica* and related species, Brassicaceae) is now the second largest oilseed crop in the world, providing approximately 13% of the world's supply and occupying approximately 2% of the world's croplands (Leff *et al.,* 2004).

Although castor oil is not edible, it is more versatile than other vegetable oils as it is widely used as a starting material for many industrial chemical products because of its unique structure. It is oane of those vegetable oils that have found usage in many chemical industries. It is a raw material for paints, coatings, inks, lubricants and a wide variety of other products. Because of its hydroxyl functionality, the oil is suitable for use in isocyanate reactions to make polyurethane elastomers, polyurethane millable (Yeganeh *et al.,* 2004), adhesives and coatings, interpenetrating polymer network from castor oil-based polyurethane and polyurethane foam (Ogunniyi *et al.,* 1996,). Some semi-rigid foam that has potential uses in thermal insulation was produced when castor oil/polyether mixture was reacted with toluene di-isocyanate (Vasishtha *et al.,* 1990). Sebacic acid, a 10-carbon dicarboxylic acid, is manufactured by heating castor oil to high temperatures (about 250°C) with alkali. This treatment results in saponification of the castor oil to ricinoleic acid that is then cleaved to give capryl alcohol (2-octanol) and sebacic acid. The preparation of sebacic acid and 2-octanol from castor oil has been reported (Das *et al.,* 1989). Although the sebacic acid yields are low, this route has been found to be cost competitive. Sebacic acid and hexamethylene di-isocyanate react through condensation polymerization to produce nylon-6,10. Furthermore, the esters of sebacic acid also are used as plasticizers for vinyl resins and in the manufacture of dioctylsebacate—a jet lubricant and lubricant in air cooled combustion motors. Capryl alcohol is used in plasticizers in the form of dicapryl esters of various dibasic acids. The pyrolysis of castor oil at 700^{O}C under reduced pressure has been used to obtain heptaldeyde and undecylenic acid. Undecylenic acid and heptaldehyde are important intermediates in the preparation of perfume formulations (Kula *et al.,* 1994). The use of new fuels and additives in automotive engines requires the assessment of compatibility with common sealing elastomers to present failures (Leonardo *et al.,* 2017). The effects of biodiesel compositional variations on engine characteristics are captured using a multilinear regression model incorporated with two new biodiesel composition based parameter viz straight chain saturation factor and modified degree of unsaturation (Mishra *et al.,* 2017). A significant portion of the energy required to electrochemically reduce CO_2 to fuels and chemicals is typically consumed by the accompanying oxygen evolution reaction. An alternative oxidative reactions using biodiesel waste could improve the economics and emission profile of this process (Bardow *et al.,* 2019). Chrysler (2007) indicated its intention to increase warranty coverage to 20% biodiesel blends if biofuel quality in the United States can be standardized (Kamp, 2006). The Volkswagen (2011) has released a statement indicating that several of its vehicles are compatible with B5 and B100 made from rape seed oil and compatible with the EN 14214 standard. Mercedes Benz does not allow diesel fuels containing greater than 5% biodiesel (B5) due to concerns about "production shortcomings". Starting in 2004, the city of Halifax, Nova Scotia decided to update its bus system to allow the fleet of city buses to run entirely on a fish-oil based biodiesel. This caused the city some initial mechanical issues, but after several years of refining, the entire fleet had successfully been converted (Halifax, 2006, 2010, 2004). Biodiesel can also be used as a heating fuel in domestic and commercial boilers, a mix of heating oil and biofuel which is standardized and taxed slightly differently from diesel fuel used for transportation. Bioheat fuel is a proprietary blend of biodiesel and traditional heating oil. Bioheat is a registered trademark of the National Biodiesel Board [NBB] and the National Oilheat Research Alliance [NORA] in the U.S., and Columbia Fuels in Canada.

Another approach is to start by Indian railway (2014, 2015) using biodiesel as a blend, and decreasing the petroleum proportion over time can allow the varnishes to come off more gradually and be less likely to clog. Thanks to its strong solvent properties, however, the furnace is cleaned out and generally becomes more efficient. A technical research paper describes laboratory research and field trials project using pure biodiesel and biodiesel blends as a heating fuel in oil-fired boilers. During the Biodiesel Expo 2006 in the UK, Andrew J. Robertson presented his biodiesel heating oil research from his technical paper and suggested B20 biodiesel could reduce UK household CO_2 emissions by 1.5 million tons per year (Robertson *et al.,* 2007).

Biodiesel is an effective solvent to oil due to its methyl ester component, which considerably lowers the viscosity of the crude oil. With 80–90% of oil spill costs invested in shoreline cleanup, there is a search for more efficient and cost-effective methods to extract oil spills from the shorelines. Biodiesel has displayed its capacity to significantly dissolve crude oil, depending on the source of the fatty acids. In a laboratory setting, oiled sediments that simulated polluted shorelines were sprayed with a single coat of biodiesel and exposed to simulated tides (French *et al.,* 2004). Biodiesel is also used in rental generators. In 2001, UC Riverside installed a 6-megawatt backup power system that is entirely fueled by biodiesel. Backup diesel-fueled generators allow companies to avoid damaging blackouts of critical operations at the expense of high pollution and emission rates. By using B100, these generators were able to essentially eliminate the byproducts that result in smog, ozone, and sulfur emissions. The use of these generators in residential areas around schools, hospitals, and the general public result in substantial reductions in poisonous carbon monoxide and particulate matter (Fernandez *et al.,* 2007).

Future prospective:

As a future prospective fuel, biodiesel has to compete economically with petroleum diesel fuels. One way of reducing the biodiesel production costs is to use the less expensive feedstock containing fatty acids such as inedible oils, animal fats, waste food oil and byproducts of the refining vegetables oils. The goal of biodiesel industries is not to replace the petroleum diesel, but to extend its usefulness. Biodiesel is one of the several alternative fuels that have a place in the development of a balanced energy policy. The role of biodiesel is to contribute to the longevity and cleanliness of diesel engine. The most likely use of biodiesel will be in certain niche markets that require a clean burning, biodegradable.

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