



Biodiesel production from non edible-oils : A Review

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ABSTRACT

Sustainable production of renewable energy is being hotly debated globally since it is increasingly understood that first generation biofuels, primarily produced from food crops and mostly oil seeds are limited in their ability to achieve targets for biofuel production, climate change mitigation and economic growth. These concerns have increased the interest in developing second generation biofuels produced from non-food feedstocks such as non-edible oils which potentially offer greatest opportunities in the longer term. A large variety of plants that produce non-edible oils can be considered for biodiesel production such as Madhuca Indica (Mahua), Jatropha curcas (Ratan Jyot), Pongamia pinnata (Karanja), Soapnut (Sapindus mukorossi) and Melia azadirachta (Neem) etc., are easily available in developing countries and are very economical comparable to edible oils. This review paper assesses and integrates about the different tree borne oilseeds, extraction of oil, biodiesel processing and effect of different parameters on production of biodiesel. If the developed process is scaled up to commercial levels then excellent business opportunity will be offered by the biodiesel and it could be a major step towards the creation of an eco-friendly transportation fuel that is relatively clean on combustion.

Keywords: Tree borne oil seeds, Non edible oils, Transesterification, Bio diesel.

INTRODUCTION

High petroleum prices demand the study of biofuel production. Lower-cost feedstocks are needed since biodiesel from food-grade oils is not economically competitive with petroleum-based diesel fuel. Non-edible plant oils have been found to be promising crude oils for the production of biodiesel. World annual petroleum consumption and vegetable oil production is about 4.018 and 0.107 billion tons, respectively [1]. The cost of biodiesel and demand of vegetable oils can be reduced by non-edible oils, instead of vegetable oil. Biodiesel is a clean burning recycled fuel made from vegetable oils. It is chemically called Fatty Acid Alkyl Ester. Even though diesel is part of its name, there are no petroleum or other fossil fuels in biodiesel. Biodiesel is 100% vegetable oil based. Biodiesel is made up of almost 10% oxygen, making it a naturally "oxygenated" fuel. It is obtained by reaction of vegetable oil with alcohol in presence of catalyst. Burning fuels derived from vegetable oils does not contribute any additional CO₂ to the atmosphere, as the carbon released is the same as the carbon absorbed by the plants as they grow. Using vegetable oils is therefore beneficial to the environment, economy and to the atmosphere.

Throughout the world, large amounts of non-edible oil plants are available in nature like Jatropha oil, Pongamia oil, Rapeseed Oil, Mahua oil, Olive oil, Rice Bran oil, Linseed oil, Soya bean oil, Palm oil, Cotton seed oil, Beef Tallow, Lard, Guang-Pi are easily available in developing countries and are very economical comparable to edible oils. The use of particular raw material depends upon the availability, price and policy. But the major obstacle for commercialization of biodiesel is its cost approximately 70-90% of biodiesel cost is arises from the cost of feed stocks [2]. Because most of the biodiesels were prepared from edible oils like soybean, sunflower, canola, palm and fish oil. Cost of edible oils is very higher than Petroleum diesel and edible oils for biodiesel production leads food versus fuel issue. The above problem can be solved by using cheapest, low cost non edible oils for biodiesel production. However the direct use of vegetable oils as fuel can cause numerous engine problems like poor fuel atomization, incomplete combustion and carbon deposition on fuel injector and engine fouling. Hence the viscosity

of vegetable oils can be reduced by several methods which include blending of oils, micro-emulsification, pyrolysis and transesterification. Among this transesterification is widely used for industrial biodiesel production. Because it gives high yield with low temperature, pressure and short reaction time.

Diesel boiling-range material from plant oils is of particular interest because it has been shown to significantly reduce particulate emissions relative to petroleum diesel fuel. The advantages of biodiesel as diesel fuel are liquid nature-portability, ready availability, renewability, higher combustion efficiency, lower sulfur and aromatic content, higher cetane number, and higher biodegradability.

The main advantages of biodiesel given in the literature include domestic origin, reducing the dependency on imported petroleum, high flash point, and inherent lubricity in the neat form. Major disadvantages of biodiesel are higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide (NO_x) emissions, lower engine speed and power, injector coking, engine compatibility, high price, and higher engine wear. Biodiesel has a higher cloud point and pour point compared to conventional diesel. Neat biodiesel and biodiesel blends increase nitrogen oxide (NO_x) emissions compared with petroleum-based diesel fuel used in an unmodified diesel engine. Peak torque is less for biodiesel than petroleum diesel but occurs at a lower engine speed and generally the torque curves are flatter. The biodiesels, on average, decrease power by 5% compared to that of diesel at rated load.

Table-1 : Annual Production of Non-edible Oil Seeds in India [3]

Type	Production (MT)	Oil %
Neem	500	30
Karanja	200	27-39
Kusum	80	34
Pilu	50	33
Ratanjot	-	30-40
Jaoba	-	50
Bhikal	-	37
Wild Walnut	-	60-70
Undi	04	50-73
Thumba	100	21

Table – 2: Fatty acid composition of Soapnut oil [5]

Fatty Acid	Structure	Amount %
Palmitic acid	16:0	4.67
Patmitoleic acid	16:1	0.37
Stearic acid	18:0	1.45
Oleic acid	18:1	52.64
Linoleic acid	18:2	4.73
Alpha or gamma- linoleic acid	18:3	1.94
Arachidic acid	20:0	7.02
Eicosenic acid	20:1	23.85
Behenic acid	22:0	1.45
Erucic acid	22:1	1.09
Lignoceric acid	24:0	0.47
Others		0.32
Total		100.00

MAJOR NON-EDIBLE TREE BORNE OILSEEDS (TBOS) SOAPNUT (SAPINDUS MUKOROSI)

Soapnut is a fruit of the soapnut tree generally found in tropical and sub-tropical climate areas in various parts of the world including Asia, America and Europe. Two main varieties (*S. mukorossi* and *S. trifoliatus*) are widely available in India, Nepal, Bangladesh, Pakistan and many other countries. The oil content in *S. trifoliatus* which is very similar to *S. mukorossi* seed kernels, was on average 51.8% of seed weight. The oil from soapnut has been considered a nonedible oil having significant potential for biodiesel production from the material which otherwise is a waste material [4]. A comprehensive study on the uses of various parts of the soapnut tree. Soapnut has several applications from medicinal treatments to soap and surfactant. Soapnut fruit shells have been in use as natural laundry detergents from ancient times for washing fabrics, bathing and traditional medicines. The recorded external use of saponin does not cite any toxic effects on human skin and eyes. These application all make use of the pericarp shell and the seeds are usually waste. Hence, the use of soapnut seeds as a biodiesel source becomes the “waste-to-energy” scheme. Furthermore, planting soapnut trees in community forestry and in barren lands provides sink for carbon sequestration as well as feedstock for biodiesel production [5]. The total value of exports of soapnut as medicinal use including other four species made up to 52% of the total non timber forest products export to India from Nepal. The totals of 32 non-timber forest products are exported with a total value of 8.1 million US dollar for

the year 1997/1998. Recently it was reported that the glycerol, a by-product of biodiesel production, can be used to produce organic acids such succinic acids by bacterial fermentation [6] Hence, the economics of biodiesel from soapnut oil can easily be realized on community scale as it can be integrated in the community forestry plan.



Figure 1, Soapnut tree



Figure 2, Soapnut fruit, seed

MAHUA (MADHUCA INDICA)

Bio diesel from mahua seed is important it is found abundantly in tribal areas . The annual production of mahua is nearly 181 Kt. Mahua is a nontraditional, & non edible oil also known as Indian butter tree. Mahua seed contain 30-40 percent fatty oil called mahua oil. Mahua is a medium to larger tree[7].In India the mahua plant is found in most of the state e.g. Orissa, Chatishgada, Jharkhand, Bihar, Madhya Pradesh ,Tamil nadu. It can be sucessesfully grown in waste land & dry land. The tree is a strong light demander and gets readily suppressed under shade. The tree has potential of enhancing rural income. The tree may attain a height of upto 20 meters and is well adapted to varied weather conditions it has wide spreading branches and circular crown which presents a visually appealing structure. The tree has a large spreading root system, though many of them are superficial. The fruit is a kind of berry, egg shaped. Mature seeds can be obtained during June to July. The mahua tree starts bearing seeds from seventh years of planning. Commercial harvesting of seeds can be done only from the tenth year. Seed yield ranges from 20 -200 kg per tree every year, depending on its growth and development [8]. As a plantation tree, Mahua is an important plant having vital socioeconomic value. This species can be planted on roadside and canal banks on commercial scale and in social forestry programs, particularly in tribal areas. Wood can be used as timber, making pulp and paper. Mahua flowers are rich in sugar, minerals, vitamins and calcium.

Table –3: Fatty acid composition of Mahua oil [9]

Fatty Acid	Structure	Amount %
Palmitic acid	16:0	16.0-28.2
Stearic acid	18:0	20.0-25.1
Oleic acid	18:1	41.0-51.0
Linoleic acid	18:2	8.9-13.7
Arachidic acid	20:0	0.0-3.3

**Figure 3. Mahua tree****Figure 4, Mahua fruit, seed****JATROPHA (JATROPHA CURCAS)**

Jatropha curcas is a drought-resistant perennial, growing well in marginal/poor soil. It produces seeds with an oil content of around 37%. The oil can be combusted as fuel without being refined. It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine. The by-products are press cake a good organic fertilizer, oil contains also insecticide. It is found to be growing in many parts of the country, rugged in nature and can survive with minimum inputs and easy to propagate. Medically it is used for diseases like cancer, piles, snakebite, paralysis, dropsy etc. Depending on soil quality and rainfall, oil can be extracted from the *Jatropha* nuts after two to five years. It grows on well drained soils with good aeration and is well adapted to marginal soils with low nutrient content. *Jatropha curcas* grows almost anywhere, even on gravelly, sandy and saline soils. It can thrive on the poorest stony soil. The leaves shed during the winter months form mulch around the base of the plant. Its water requirement is extremely low and it can stand long periods of drought by shedding most of its leaves to reduce transpiration loss. *Jatropha* is also suitable for preventing soil erosion and shifting of sand dunes [10].

Table – 4: Fatty acid composition of Jatropha oil [11]

Fatty Acid	Structure	Amount %
Palmitic acid	16:0	13.38
Patmitoleic acid	16:1	0.88
Stearic acid	18:0	5.44
Oleic acid	18:1	45.79
Linoleic acid	18:2	32.27
Lauric acid	12:0	0.31
Others		1.93
Total		100.00

**Figure 5, Jatropha tree****Figure 6, Jatropha fruit, seed****KARANJA (PONGAMIA PINNATA)**

The botanical name of Karanja seed Oil and is *Pongamia glabra* of Leguminaceae family. *Pongamia* is widely distributed in tropical Asia and it is nonedible oil of Indian origin . It is found mainly in the Western Ghats in India, northern Australia, Fiji and in some regions of Eastern Asia. .The plant is also said to be highly tolerant to salinity and can be grown in various soil textures viz. stony, sandy and clayey. Karanja can grow in humid as well as subtropical environments with annual rainfall ranging between 500 and 2500 mm. This is one of the reasons for wide availability of this plant species. The tree bears green pods which after some 10 months change to a tan colour. The pods are flat to elliptic, 5-7 cm long and contain 1 or 2 kidney shaped brownish red kernels. The yield of kernels per tree is reported between 8 and 24 kg. .The kernels are white and covered by a thin reddish skin. The composition of typical air dried kernels is: Moisture 19%, Oil 27.5%, and Protein 17.4%. The present production of karanja oil approximately is 200 million tons per annum. The time needed by the tree to mature ranges from 4 to 7 years and depending on the size of the tree the yield of kernels per tree is between 8 and 24 kg. The oil content extracted by various authors ranges between 30.0 to 33% [12].The oil is used by common people due to its low cost and easy availability.

Table – 5: Fatty acid composition of Karanja oil [12]

Fatty Acid	Structure	Amount %
Palmitic acid	16:0	3.7-7.9
Stearic acid	18:0	2.4-8.9
Oleic acid	18:1	44.5-71.3
Linoleic acid	18:2	10.8-18.3
Lignoceric acid	24:0	1.1-3.5

**Figure 7, Karanja tree****Figure 8, Karanja fruit, seed****NEEM (MELLIA AZADIRACHTA)**

Neem (*Mellia azadirachta*) is of Meliaceae family. The other names of neem are Margosa, Veppam, Vepun, Nimba and Vepa (Telugu) etc. It is one of the two species in the genus *Azadirachta*, and is native to India and Burma, growing in tropical and semi tropical regions. Neem is a fast growing tree and can reach upto a height of 15 – 20 to 35 – 40 m. It bears an ovoid fruit, 2cm by 1cm and each seed contains one kernel. The seed kernels, which weigh 0.2g, constitute some 50-60% of the seed weight and 25% of the fruit. The fat content of the kernels ranges from 33-45%.^[10] The fruit yield per tree is 37-55 kg.. Neem oil can be used as Soaps, medicinal and insecticide . Neem oil is usually opaque and bitter but it has recently been shown that it can be processed into non bitter edible oil with 50% oleic acid and 15% linoleum acid. The bitter cake after extraction of oil has no value for animal feeds although it has been reported that after solvent extraction with alcohol and hexane a meal suitable for animals is produced. Neem seeds are usually crushed prior to extraction in ghanis. Whole dried fruits may be directly passed to expellers. Good quality kernels (50% oil) yield 40% oil in ghanis. In expellers whole dried fruits, depulped seeds and kernels, yield 4-6%, 12-16% and 30-40% oil respectively (Bring)). The cakes, which contain 7-12% oil are sold for solvent

extraction. Major fatty acid composition of oil are Palmitic acid 19.4%,Stearic acid 21.2%,Oleic acid 42.1%,Linoleic acid 14.9%,Arachidic acid 1.4%[13]

Neem oil is unusual in containing non-lipid associates often loosely termed as "bitters" and organic sulphur compounds that impart a pungent, disagreeable odour.

Table – 6: Fatty acid composition of Neem oil [14]

Fatty Acid	Structure	Amount %
Palmitic acid	16:0	17.8
Stearic acid	18:0	14.4
Oleic acid	18:1	51.3
Linoleic acid	18:2	14.7
Arachidic acid	20:0	1.6
Myristic acid	14:0	0.03



Figure 9, Neem tree



Figure 10, Neem fruit, seed

OIL PROCESSING TECHNOLOGY OF OIL SEEDS

Oil extraction and Purification of Oil

Oil extraction methods are being developed based on fermentation hydrolysis. In this process, cell walls of the oil plant seeds are destroyed followed by the release of the oil present within the cells. This new method not only produces higher quality of oil and cake but also requires much less energy and results in lower levels of environmental pollution. The efficiency so far obtained is 86% and more research is needed to develop an effective enzyme system. The extracted oil can be purified by Sedimentation process. This is the easiest way to get clear oil,

but it takes about a week until the sediment is reduced to 20 - 25 % of the raw oil volume. The purification process can be accelerated tremendously by boiling the oil with about 20 % of water[15]

Detoxification of seed cake

After extraction of oil from seed the detoxification of the seed cake is necessary so that the seed cake can be used as cattle feed. The type of toxic component present in the seedcake varies from seed to seed. From Several investigations it is found that de-acidification and bleaching could reduce the content of toxic phorbol esters to 55%. Efficiency of the treatment also depends upon the type of toxic component present in the seedcake and the effective detoxification techniques[16]

BIODIESEL PROCESSING

The alternative diesel fuels must be technically and environmentally acceptable, and economically competitive. From the viewpoint of these requirements, triglycerides (vegetable oils/animal fats) and their derivatives may be considered as viable alternatives for diesel fuels. The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. The problems have been mitigated by developing vegetable oil derivatives that approximate the properties and performance and make them compatible with the hydrocarbon-based diesel fuels through:

- (i) pyrolysis;
- (ii) microemulsification;
- (iii) dilution;
- (iv) and transesterification.

PYROLYSIS

Pyrolysis refers to a chemical change caused by the application of thermal energy in the absence of air or nitrogen. The liquid fractions of the thermally decomposed vegetable oil are likely to approach diesel fuels. The pyrolyzate had lower viscosity, flash point, and pour point than diesel fuel and equivalent calorific values. The cetane number of the pyrolyzate was lower. The pyrolysed vegetable oils contain acceptable amounts of sulphur, water and sediment and give acceptable copper corrosion values but unacceptable ash, carbon residue and pour point.

MICRO-EMULSIFICATION

The formation of microemulsions (co-solvency) is one of the potential solutions for solving the problem of vegetable oil viscosity. Micro-emulsions are defined as transparent, thermodynamically stable colloidal dispersions. The droplet diameters in micro-emulsions range from 100 to 1000 Å. A micro-emulsion can be made of vegetable oils with an ester and dispersant (co-solvent), or of vegetable oils, an alcohol and a surfactant and a cetane improver, with or without diesel fuels. Water (from aqueous ethanol) may also be present in order to use lower-proof ethanol, thus increasing water tolerance of the micro-emulsions[17].

DILUTION

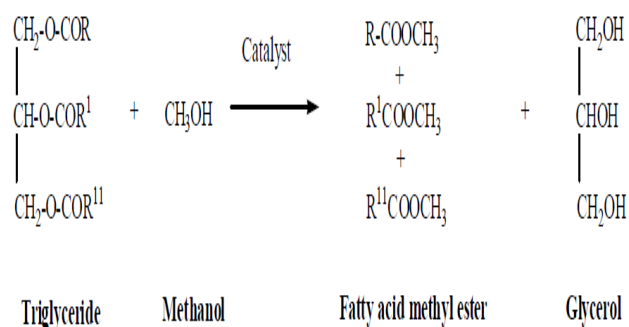
Dilution of vegetable oils can be accomplished with such materials as diesel fuels, solvent or ethanol. The vegetable oil is diluted with petroleum diesel to run the engine. Caterpillar Brazil, in 1980, used pre-combustion chamber engines with the mixture of 10% vegetable oil to maintain total power without any alteration or adjustment to the engine. At that point it was not practical to substitute 100% vegetable oil for diesel fuel, but a blend of 20% vegetable oil and 80% diesel fuel was successful. Some short-term experiments used up to a 50/50 ratio[18].

TRANSESTERIFICATION

Transesterification also called alcoholysis, is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis. This process has been widely used to reduce the viscosity of triglycerides. The transesterification reaction is represented by the general equation



If methanol is used in the above reaction, it is termed methanolysis. The reaction of triglyceride with methanol is represented by the general equation:



Triglycerides are readily trans-esterified in the presence of alkaline catalyst at atmospheric pressure and at a temperature of approximately 60 to 70°C with an excess of methanol. The mixture at the end of reaction is allowed to settle. The lower glycerol layer is drawn off while the upper methyl ester layer is washed to remove entrained glycerol and is then processed further. The excess methanol is recovered by distillation and sent to a rectifying column for purification and recycled.

The transesterification works well when the starting oil is of high quality. However, quite often low quality oils are used as raw materials for bio-diesel preparation. In cases where the free fatty acid content of the oil is above 1%, difficulties arise due to the formation of soap which promote emulsification during the water washing stage and at an FFA content above 2% the process becomes unworkable[19].

EFFECT OF DIFFERENT PARAMETERS ON PRODUCTION OF BIODIESEL

Process Variables

The most important variables that influence the transesterification reaction are as follow:

REACTION TEMPERATURE

The rate of reaction is strongly influenced by the reaction temperature. However, given enough time, the reaction will proceed to near completion even at room temperature. Generally, the reaction is conducted close to the boiling point of alcohol at atmospheric pressure. These mild reaction conditions require the removal of free fatty acids from the oil by refining or pre-esterification. Further increase in temperature is reported to have a negative effect on the conversion. The rate of reaction is strongly influenced by the reaction temperature. Further increase in temperature is reported to have a negative effect on the conversion. Literature Studies have indicated that given enough time, transesterification can proceed satisfactorily at ambient temperatures in the case of the alkaline catalyst. It was observed that bio-diesel recovery was affected at very low temperatures but conversion was almost unaffected.^[20]

RATIO OF ALCOHOL TO OIL

Another important variable affecting the yield of ester is the molar ratio of alcohol to oil. The stoichiometry of the transesterification reaction requires 3mol of alcohol per mole of triglyceride to yield 3mol of fatty esters and 1 mol of glycerol. To shift the transesterification reaction to the right, it is necessary to use either a large excess of alcohol or to remove one of the products from the reaction mixture. When 100% excess alcohol is used, the reaction rate is at its highest. Higher molar ratio of alcohol to oil interferes in the separation of glycerol. It was observed that lower molar ratios required more reaction time. With higher molar ratios, conversion increased but recovery decreased due to poor separation of glycerol. It was found that optimum molar ratios depend upon type & quality of oil[21].

CATALYST TYPE AND CONCENTRATION

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. Transmethylations occurs approximately 4000 times faster in the presence of an alkaline catalyst than those catalyzed by the same amount of acidic catalyst. Partly for this reason and partly because alkaline catalysts are less corrosive to industrial equipment than acidic catalysts, most commercial transesterification are conducted with alkaline catalysts. Further, increase in catalyst concentration does not increase the conversion and it adds to extra costs because it is necessary to remove it from the reaction medium at the end. Further, increase in catalyst concentration does not increase the conversion and it adds to extra costs because it is necessary to remove it from the reaction medium at the end. It was observed in literature studies higher amounts of NaOH catalyst were required for higher FFA oil[22].

PURITY OF REACTANTS

Impurities present in the oil also affect conversion levels. Under the same conditions, 67 to 84% conversion into esters using crude oils can be obtained, compared with 94 to 97% when using refined oils. The free fatty acids in the original oils interfere with the catalyst, under conditions of high temperature and pressure this problem can be

overcome. It was observed that crude oils were equally good compared to refined oils for production of bio-diesel. However, the oils should be properly filtered. Oil quality is very important in this regard [12].

MIXING INTENSITY

The mixing is most significant during the slow rate region of the transesterification reaction. As the single phase is established, mixing becomes insignificant. The understanding of the mixing effects on the kinetics of the transesterification process is a valuable tool in the process scale-up and design. It was observed in literature studies that after adding alcohol & catalyst to the oil, 5-10 minutes stirring helps in higher rate of conversion and recovery[12].

EFFECT OF ALCOHOL TYPE

Methanol gave the best biodiesel yield, followed by butanol and least was with ethanol. There are many reasons behind it. Firstly, Methanol is simpler in terms of chemical structure, thus the transesterification reaction is more likely to occur. Butanol and ethanol are more complex in terms of chemical structures; therefore it is more difficult for transesterification to occur. Secondly, the base catalyzed formation of ethyl ester is difficult compared to the formation of methyl esters. In the case of methanolysis, formation of emulsions quickly and easily breaks down to form a lower glycerol rich layer and upper methyl ester rich layer. In ethanolysis, these emulsions are more stable and severely complicate the separation and purification of esters.[23]

EFFECT OF REACTION TIME

The conversion of oil to biodiesel approaches to equilibrium conversions with increased reaction times. The maximum ester conversion is obtained at 2 hour reaction time. Similar reaction time has been reported in *Madhuca Indica* and *Karanja* oil have reported that the reaction is very slow during the first minute due to mixing and dispersion of methanol into catalyst. From 1 to 5 min, the reaction proceeded very fast. The production of beef tallow methyl esters reached the maximum value at about 15 min[24]

EFFECT OF MOISTURE AND WATER CONTENT ON THE YIELD OF BIODIESEL

Water could pose a greater negative effect than presence of free fatty acids and hence the feedstock should be free from water. Even a small amount of water (0.1%) in the transesterification reaction would decrease the ester conversion from vegetable oil. The yield of the alkyl ester decreases due to presence of water and FFA as they cause soap formation, consume catalyst and reduce the effectiveness of catalyst. Moisture content from the vegetable oil is removed by heating in oven for 1 h at 383 K. Meher *et al.* too reported a precautionary step to prevent moisture absorbance and maintenance of catalytic activity by preparing the fresh solution of potassium hydroxide and methanol. It is found that even a small amount of water in the feedstock or from esterification reaction producing water from FFA might cause reduction in conversion of fatty acid methyl ester and formation of soap instead. At the same time the presence of water had a positive effect in the yield of methyl esters when methanol at room temperature was substituted by supercritical methanol. However, no explanation for this has been provided. The presence of water had negligible effect on the conversion while using lipase as a catalyst [3].

EFFECT OF FREE FATTY ACIDS

Free fatty acids (FFAs) content after acid esterification should be minimal or otherwise less than 2% FFAs. These FFAs react with the alkaline catalyst to produce soaps instead of esters. There is a significant drop in the ester conversion when the free fatty acids are beyond 2% [25].

EFFECT OF STIRRING

Stirring can play an important role in the yield of biodiesel production. Transesterification reaction was carried out with 180, 360 and 600 revolutions per minute (rpm) and reported incomplete reaction with 180 rpm. The yield of methyl ester was same with 360 and 600 rpm. Mode of stirring too plays a vital role in the transesterification reaction. The yield of biodiesel increased from 85% to 89.5% when magnetic stirrer (1000 rpm) was replaced with mechanical stirrer (1100 rpm). A plausible explanation may be a thorough mixing of the reactants by mechanical stirrer [26].

EFFECT OF SPECIFIC GRAVITY

Lower value of the specific gravity of the final product is an indication of completion of reaction and removal of heavy glycerine. The influence of molar ratio, temperature and catalyst quantity on the specific gravity of the biodiesel was studied by Miao and Wu. The specific gravity of the product decreased sharply up to 2 h of reaction time using 30:1 molar ratio and up to 4 h of reaction time using 45:1 and 56:1 molar ratio after which it was almost constant. The best process combination reduced the product specific gravity from 0.912 to 0.864 with 100% catalyst, 56:1 molar ratio at 303 K in 4 h of reaction time[27]

By analyzing these variables we can get maximum yield of biodiesel from non-edible oils.

HANDLING & STORAGE OF BIO-DIESEL

As a general rule blends of bio-diesel and petroleum diesel should be treated like petroleum diesel. Bio-diesel vegetable methyl esters contain no volatile organic compounds that can give rise to poisonous or noxious fumes. There is no aromatic hydrocarbon (benzene, toluene, xylene) or chlorinated hydrocarbons. There is no lead or sulfur to react and release any harmful or corrosive gases. However, in case of bio-diesel blends significant fumes released by benzene and other aromatics present in the base diesel fuel can continue. On eye contact bio-diesel may cause eye irritation. Safety glasses or face shields should be used to avoid mist or splash on face and eyes. Fire fighting measures to be followed as per its fire hazard classification. Hot fuel may cause burn. Bio-diesel should be handled with gloves as it may cause soft skin. Mild irritation on skin can occur.

For long term Storage stability of Bio-diesel and blends adequate data are not available. Based on experience so far it is recommended that bio-diesel can be store up to a maximum period of 6 months. Some anti-oxidant additives are also used for longer periods of storage. Similarly periods are applicable for storage of bio-diesel and its blends in vehicle fuel tank. Due to being a mild solvent, bio-diesel has a tendency to dissolve the sediments normally encountered in old tanks used for diesel fuel and cause filter blockage, injector failures in addition to clogging of fuel lines. Brass, copper, zinc etc oxidizes diesel and bio-diesel fuels and create sediments. The fuel and fitting will start changing color as the sediments are formed. Storage tank made of aluminum, steel etc should be used.

STABILITY OF BIO DIESEL

Bio-diesel ages more quickly than fossil diesel fuel due to the chemical structure of fatty acid esters present in bio-diesel. There are three types of stability criteria, which need to be studied:

(a) Oxidation stability (b) Thermal Stability and (c) Storage Stability

Poor oxidation and thermal stability can cause fuel thickening, formation of gum and sediments and may also affect engine oil due to dilution. Current knowledge and database is still inadequate. It is desirable to carry out tests on bio-diesel from different feedstocks available and generate data in relation to fuel composition. Very little data is available on the long-term storage stability of bio-diesel.

BIODEGRADABILITY OF BIODIESEL

Biodiesel is highly biodegradable in freshwater as well as soil environments. 90–98% of biodiesel is mineralized in 21–28 days under aerobic as well as anaerobic conditions [28]. Biodiesel has been reported to remove twice the amount of crude oil from sand as conventional shoreline cleaners [29]. Biodiesel increases the biodegradability of crude oil by means of co metabolism. More than 98% degradation of pure biodiesel after 28 days in comparison to 50% and 56% by diesel fuel and gasoline respectively. Also, the time taken to reach 50% biodegradation reduced from 28 to 22 days in 5% biodiesel mixture and from 28 to 16 days in case of 20% biodiesel mixture at room temperature. The biodegradability of the mixture was reported to increase with addition of biodiesel. And it depicts the biodegradability of fossil diesel under different conditions [30].

CONCLUSION

With the increase in global human population, more land may be needed to produce food for human consumption (indirectly via animal feed). The problem already exists in Asia. Vegetable oil prices are relatively high there. The same trend will eventually happen in the rest of the world. This is the potential challenge to biodiesel. From this point of view, biodiesel can be used most effectively as a supplement to other energy forms, not as a primary source. Biodiesel is particularly useful in mining and marine situations where lower pollution levels are important. Biodiesel also can lower US dependence on imported petroleum based fuel.

The high consumption of diesel fuels and limited sources of the others are reasons for an enormous rise in price of petroleum fuels. The Vegetable oils hold special promise in this regard since they can be produced from plants grown in waste lands like *Jatropha*, *Mahua*, *Neem*. These are clean burning, renewable, non-toxic, biodegradable and environmentally friendly transportation fuels that can be used in neat form or in blends with petroleum derived diesel in diesel engines. The production of biodiesel from edible oil is currently much more expensive than diesel fuels due to relatively high cost of edible oil. There is a need to explore non-edible oils as alternative feed stock for the production of biodiesel from non-edible oils like *Karanja*, *Neem*, *Jatropha*, *Mahua*, *Soapnut* etc. owing to big climatic diversity, there are numerous oil bearing seed plants/trees available. Extraction of the oil from these plants and its conversion to bio-diesel involves energy consumption at various stages starting from the plantation to the end use in the compression ignition engine.

World annual petroleum consumption and vegetable oil production is about 4.018 and 0.107 billion tons, respectively. A large variety of plants that produce non-edible oils can be considered for biodiesel production. Non-edible oils are easily available in many parts of the world and are very cheap compared to edible oils. The cost of biodiesel and demand of vegetable oils can be reduced by non-edible oils instead of vegetable oils. Biodiesel can be derived from non-edible vegetable oil and has good potential as an alternative diesel fuel. Non-edible plant oils have been found to be promising crude oils for the production of biodiesel. Non-edible oils are very important for developing and petroleum-poor countries.

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