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Use of Non-Edible Vegetable Oils As Fuel For Diesel Engine: A Review

K.S. Mehra[1], M.P.Shah[2], S.Singh[3]

[1,2,3]Department of Mechanical Engineering, BipinTriphatiKumaon Institute of Technology, Dwarahat, 263653, Almora, Uttarakhand, India

Abstract- As we know the store of fossil fuels falling throughout the world and demands for energy based relaxations and mobility ever increasing, so there is a necessity to raise biodiesel production. Biodiesel is an alternative diesel fuel prepared from renewable resources and is most popular as because it is non-toxic and biodegradable. India has great possibilityfor production of biodiesel from non-edible oils.Performance Evaluation of single and multi-cylinder CI engine using neat non-edible vegetable oil, blended oil with diesel, methyl ester of oil, and blended bio-diesel with diesel is done by various researchers. In the present paper attempt is made to outline the research work done on non-edible oil obtained from Karanj, Jatropha, Mahua and Neem and its performance in CI engine. Moreover, notable work had been done to improve the yield of bio-diesel by varying critical parameter of esterification process. If the developed process is ascended up to commercial levels then brilliant 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 and provides farmers with substantial income.

Keywords- Bio-diesel, Non edible oils, trans-esterification,CI Engine, Blend, Methyl Ester

I. INTRODUCTION

India imported about 2/3rd of its petroleum requirements last year, which involved a cost of approximately Rs. 80,000 crores in foreign exchange. Even 5% replacement of petroleum fuel by bio-fuel can help India save Rs.4000 crores per year in foreign exchange. It is utmost important that the options for substitution of petroleum fuels be explored to control this burgeoning import bill. The degrading air quality in our cities further warrants the quest for alternate cleaner fuels. Several sources of energy, especially for driving the auto motives are being developed and tested. Bio-diesel is fatty acid methyl or ethyl ester made from virgin or used vegetable oils (both edible & non-edible) and animal fats. In India, as edible oils are in short supply, non-edible tree borne oilseeds (TBOs) of karanja, Jatropha, Mahua and Neem are being considered as the source of straight vegetable oil (SVO) and biodiesel. Plant species, which have 30% or more fixed oil in their seeds or kernel, have been identified [1]. Traditionally thecollection and selling of tree-based oilseeds was generally carried out by poor people for use as fuel for lighting. Presently there is an extended use of these oils in soaps, varnishes, lubricants, candles, cosmetics, etc. However, the current utilization of non-edible oilseeds is very low. There are many ways and procedures to convert vegetable oil into a Diesel like fuel, the trans-esterification process was found to be the most viable process [2].Trans-esterification is the process of using an alcohol (e.g. methanol, ethanol or propanol), in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to break the molecule of the raw renewable oil chemically into methyl or ethyl esters of the renewable oil, with glycerol as a byproduct.Trans-esterified oils have proven to be a viable alternative diesel engine fuel with characteristics similar to those of Diesel fuel. Its physical and chemical properties required for operation ofdiesel engine are similar to petroleum based diesel fuel. [3] Just like petroleum diesel, biodiesel operates in compression-ignition engines. Trans-esterification is a chemical reaction that aims at substituting the glycerol of the glycerides with three molecules of monoalcohols such as methanol thus

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leading to three molecules of methyl ester of vegetable oil. [4]. the molecular weight of ester molecule is 1/3rd of oil and low viscosity. Methanol and ethanol is widely used in the trans-esterification .Methanol is used because of low cost, and physicochemical advantages with triglycerides and sodium hydroxide [5]. The alkali hydrolysis of the oil must have acid value <1 and moisture content of <0.5%. The acid catalyst is the choice for trans-esterification when low-grade vegetable oil used as raw material because it contains high free fatty acid (FFA) and moisture.

II. MAJOR NON-EDIBLE OILS

A. Mahua (Madhuca Indica)

Biodiesel from mahua seed is important because most of the states of India are tribal where it is found abundantly. The annual production of mahua is nearly 181 Kt. Mahua is a non-traditional, non-edible oil also known as Indian butter tree. Mahua seed contain 30-40 percent fatty oil called mahua oil[6-11]. Mahua is a medium to larger tree. In India the mahua plant is found in most of the state e.g. Orissa, Chhattisgarh, Jharkhand, Bihar,Madhya Pradesh, and Tamil Naidu. It can be successfully 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. As a plantation tree, Mahua is an important plant having vital socioeconomic value. This species can be planted on roadside, canal banks etc 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. The fatty acid composition of mahua oil oil has been reported in Table1.

Table 1. Fatty acid composition of Mahua oil[5]

Fatty Acid	Formula	Structure	Wt%
Palmitic	$C_{16}H_{32}O_2$	16:0	16.0–28.2
Stearic	$C_{18}H_{36}O_2$	18:0	20.0–25.1
Arachidic	$C_{20}H_{40}O_2$	20:0	0.0–3.3
Oleic	$C_{18}H_{34}O_2$	18:1	41.0–51.0
Linoleic	$C_{18}H_{32}O_2$	18:2	8.9–13.7

B.Jatropha (Jatropha Curcas)

Jatropha curcus is a drought-resistant perennial, growing well in marginal/poor soil. Jatropha the wonder plant 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. The fatty acid composition of jatropha oil has been reported in Table 2.

Table 2. Fatty acid composition of Jatropha oil [11]

Fatty Acid	Formula	Structure	Wt%
Palmitic	$C_{16}H_{32}O_2$	16:0	12.0–7.0
Stearic	$C_{18}H_{36}O_2$	18:0	5.0-9.7
Myristic	$C_{12}H_{28}O_2$	24:0	0.5–1.4
Oleic	$C_{18}H_{34}O_2$	18:1	37–63
Linoleic	$C_{18}H_{32}O_2$	18:2	19–41

C. Karanja (Pongamia Pinnata)

Karanja is a medium sized tree is found almost throughout India. Karanja tree is wonderful treealmost like neem tree. The common name of the oil is Karanja Seed Oil and the botanical name 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,

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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 growin 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% [1]. The oil is used by common people due to its low cost and easy availability. The fatty acid composition of karanja oil has been reported in Table 3.

Table 3. Fatty acid composition of Karanja oil [11]

Fatty Acid	Formula	Structure	Wt%
Palmitic	$C_{16}H_{32}O_2$	16:0	3.7–7.9
Stearic	$C_{18}H_{36}O_2$	18:0	2.4–8.9
Lignoceric	$C_{20}H_{40}O_2$	24:0	1.1–3.5
Oleic	$C_{18}H_{34}O_2$	18:1	44.5–71.3
Linoleic	$C_{18}H_{32}O_2$	18:2	10.8–18.3

D. Neem

Neem (Mellia azadirachta) is of Meliaceae family. The other names of neem are Margosa,Veppam, Vepun, Nimba and Vepa (Telugu) etc**[13-15]**.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 merrily 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 thekernels ranges from 33-45%. 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%.Neem oil is unusual in containing non-lipid associates often loosely termed as "bitters" and organic sulphur compounds that impart a pungent, disagreeable odour.

III. ESTERIFICATION

Normally most of the oils are converted into biodiesel esters using the base catalysed transesterification method. But there are certain exceptional cases wherein direct trans-esterification cannot be performed. Such cases appear in raw vegetables oils(Non edible oil) like karanja oil, mahua oil, Nim,Jatropha and sal oil, etc because these raw vegetable oils posses high free fatty acid (FFA). For determining whether the raw vegetable oils can be trans-esterified directly the acid value is the most important property that must be known. If the acid value <3 then the raw vegetable oil can be directly trans-esterified. If the acid value >3 then there is slight change in the production process. At first the oil undergoes esterification and then followed by transesterification. In the esterification process the excess of the free acid gets reacted. The remainingacid content in the oil undergoes trans-esterification. So this method is effective for oils thatcontain high free fatty acid (FFA) content. So the selection of acid catalyst is very important. The aim of esterification reaction is to remove water during processing otherwise seriously hurt the reaction conversions.

III.TRANSESTERIFICATION

Transesterification also called alcoholysis is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis, except that an alcohol is employed instead of water. Suitable alcohols include:methanol, ethanol, propanol, butanol, and amyl alcohol. Methanol and ethanol are utilized most frequently. This process is widely used to reduce the viscosity of triglycerides, thereby enhancing the physical properties of fuel and improve engineperformance. Thus fatty acid methyl ester (also known as biodiesel) is obtained bytransesterification.

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IV.PERFORMANCE OF OIL IN CI ENGINE

A.Straight Vegetable Oil

Straight vegetable oil can be used as fuel for CI engine without any modification. Overallperformance of engine with SVO, SVO/diesel blend is inferior to diesel. Lower brake thermal efficiency and higher brake specific fuel consumption found compared to diesel. Higher SVO percentage in blends, results in poor emission characteristics and very high fuel consumption. Hotti et al. [16] investigated the performance of single cylinder DI diesel engine using neat karanj oil (K100) andblending karanj oil with diesel name K10, K15, K20 and compared result with diesel. In their work, they found using blends as fuel both specific fuel consumption and fuel consumption increases compared to diesel. This increase is attributed towards the lower calorific value of karanj oil. The blend K15 has minimum fuel consumption and brakespecific fuel consumption compared to other blends and neat karanj oil [16]. This close performance to diesel may be due to closer property of blend to the diesel. The heat release rate is also lower for allblends and neat karanj oil compared to diesel due tolower volatility of karanj oil and high viscosity. K15 blend again show the highest heat release compare to K10, K20 and K100 [16]. A Swarna Kumar et al. [17]investigated performance of diesel engine with neem oil and blend of neem oil with diesel. Fuel consumption and brake specific fuel consumption are measured with B10, B20, B30, B40, B50, B60, B100 and neat diesel. Both parameters are measured higher with blends compare to diesel and B10 has the lowest fuel consumption and brake specific fuel consumption compared to remaining blends [17]. The results obtained from the study strengthen the investigation by Hotti et al. [16] . Further investigation with varying injection pressure revealed that as fuel injection pressure increases, specific fuel consumption is reduced. After optimum value ofinjection pressure, further increasing in fuel injection pressure increases specific fuel consumption for lower concentration blends. However, higher concentrated blends show improvement in result. These results justify the effect of viscosity on fuel consumption and droplet diameter. Vijittra et al. [18]tested performance of fuel/fuel blends of J5, J10, J20, J50, J80, J100 and diesel in DI diesel engine. The diesel showed higher thermal efficiency than other fuel except J5, this may be due to comparable calorific value of J5 and diesel [18]. Also, oxygen present in the oil improves completeness of combustion and in turn, thermal efficiency. Effect of viscosity on performance is also measured. Viscosityvaried by either preheating the fuel or blending Jatropha oil with diesel. The blend which is having comparable viscosity to diesel has performed very close to diesel. Emission of CO and HC is more with higher percentage of oil proportion due to larger droplet diameter (high viscosity) leads to incompletecombustion. But emission of NOx is reducedcompared to diesel because of lower exhaust gas temperature with lower heat release rate (low Volatility and Higher droplet diameter). It is seen that lower proportion of oil (up to 15%) can be directlyblended with dieselwithout any modification ofengine and operating parameters.

B.Bio-Diesel in CI Engine

The property of bio-diesel is very comparative todiesel. The viscosity of bio-diesel is 5-7 times morethan that of diesel. This lower viscosity of bio-dieselreduces problems associated with vegetable oil suchas clogging, higher emission of COand HC,

requirement of higher injection pressure andpreheating of fuel. Bio-diesel can be blended in anypercentage with diesel without any enginemodification. The performance of blend up to 20 % has shown brake thermal efficiency and brakefuel consumption same as diesel andemission of CO and HC is reduced compared todiesel. Whereas the blends above 20 % have lowerthermal efficiency due to low volatility of bio-diesel results in lower rate of heat release. T. Venkateshwara et al. [19] carried out experiment on CIengine using methyl ester of Pongamia, Jatropha andNeem. The brake thermal efficiency of blend, with

20% bio-diesel by volume and 80% petroleum dieselis nearly that of using diesel. Further study showsthat smoke, CO and HC emissions are less than dieselat any load. Among three methyl esters of non-edibleoil used performance of Karanj methyl ester is thebest followed by Jatropha methyl ester and Neemmethyl ester. The decrease in thermal efficiency isdue to lower calorific value of bio-diesel. At lowerblend percent the oxygen content in the bio-diesel islower and hence the effect of lower calorific valuetakes over and results in lower brake thermalefficiency. At higher blend percentage the lowercalorific value and volatility problem associated withbio-diesel dominates and resulting in lower brakethermal efficiency compared to diesel. At blend with

20% bio-diesel by volume and 80% petroleum dieseloxygen content of bio-diesel helps in completecombustion and thermal efficiency is very close todiesel.

V.RECENT RESEARCH

Research work is carried out by many researchersinvestigate effect of addition of gaseous fuel toinducted air on performance of bio-diesel fuelledengine. The gases like hydrogen and CNG areintroduced in air intake manifold. This

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duel fuelmode allows bio-diesel to perform nearly as diesel. Insuch experiment, Venkatesan M. [20] investigated theperformance of diesel engine running on Jatropha oilMethyl ester and CNG in duel fuel mode. The resultsare encouraging compared to neat bio-diesel performance in engine. At low load the BSFC ishigher than diesel but with increasing load the BSFCapproaches to that of diesel. Increasing the injectionpressure further reduces the BSFC. Combine effect ofadvancing the injection timing and increase in
injection pressure lowers the value of BSFC morethan diesel at full load. Brake thermal efficiencyshowing the same results as BSFC. With dual fuelmode the emission of CO, HC is reduced but is morethan diesel. Further reduction in emission is possible
by increasing injection pressure and advancinginjection timing. Trade off should be designed foradvancing the injection timing and increase ininjection pressure because increase in NOx emission.Jacob Wall [21] carried out performance measurement of diesel engine using Jatropha oil and hydrogen. At full load, brake thermal efficiency increases with increase in hydrogen but at part load efficiency decreases with increase in hydrogen share. Emission of CO is reduced with increasing hydrogen share.

VI. FUTURE OF BIODIESEL IN INDIA

India has great potential for production of biodiesel from non-edible oil seeds. From about 100 varieties of oil seeds, only 10-12 varieties have been tapped so far. The annual estimated potential is about 20 million tonnes per annum. Wild crops cultivated in the westland also form a source of biodiesel production in India and according to the Economic Survey of Government ofIndia, out of the cultivated land area, about 175 million hectares are classified as waste and degraded land. Thus, given a demand-based market, India can easily tap its potential and produce biodiesel in a large scale. Table4. depicts the annual production of non-edible oil seeds in India.**G**overnment agencies like Ministry of Rural Development, Environment and Forestry, Petroleum and Natural Gas, Agriculture, and Non-Conventional Energy Source can all play leading roles in this program.. Industry and research institutes have also the vital role for the success and a clear supply chain mechanism with utilization plan is necessary in national level like elsewhere across the globe. research organizations should be encouraged to undertake LifeCycle Analysis exercise for bio diesel produced from varied feedstock being used India andneed to quickly develop high-yielding varieties of plants for various regions .Both scientific and agricultural research bodies should be involved directly and on a regular basis to regularly enhance the efficiency levels of both production and processing of bio diesel..It is required toselect and evolve quick growing and high-yield varieties and improved methods of propagation to produce better quality oil and to provide farmer's with a choice of Tree Borne Oil (TBO)species that are most appropriate to local agro-climatic conditions The seed collection and the processing of raw oil could also be taken up as a cooperative movement, which has led to severalsuccess stories in India. Small and medium scale industrial sector are required to take initiative for the downstream processing of raw oil and its supply to petroleum marketing companies .At the national level it is required to set up a very effective task force for the coordination of plantation, production, distribution and marketing activities.The Government of India through itsPlanning Commission has initiated a national program to cultivate vast areas of waste lands by plantation of oil-bearing trees and as a result of this, substantial quantities of biodiesel can be available in the near future.

Table 4. Annual Production of Non-edible Oil Seeds in India [11]

Type	Production	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

VII.CONCLUSION

Edible oils are in use in developed nations such as USA and European nations but in developing countries the production of edible oils are not sufficient . In a country like India, there are many plant species whose seeds remain unutilized and underutilized have been tried for biodiesel production. Non-edible oil seeds are the potential feedstock for production of biodiesel in India. These species have shown promises and fulfills various biodiesel standards. Up to 10 % of non edible oil can be blended with diesel without any need of engine modification and impairing performance. Esters obtained from these non edible oil further expands the limit of blend to 20 % with similar engine performance. However, the performance of pure bio-diesel in CI engine without any modification is far

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from the diesel and not satisfactory.India, with its huge waste/non-fertile lands, has taken a well noted lead in the area and commercial production.Proper processing of non-edible oil seeds and transesterification can ascertain the quality ofbiodiesel and can be fulfill the large commercial application .The future success of these non-edible oil as a sustainable source of feedstock for the biofuels industry is reliant on an extensive knowledge of the genetics, physiology,and propagation of these species. In particular, research should be targeted to maximizing plant growth as it relates to oil biosynthesis.

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