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Jatropha Oil as a Potential Fuel for C.I. Engines

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Abstract: -- **Energy is the main input in the technological, socio-economical, and industrial development of any country. Petroleum-derived Fuels are the major source of energy throughout the world. However, these fuels are not only limited but also pollute the environment. In India, the diesel fuel is extensively used in transportation, agriculture, and industrial sector and the consumption of diesel is four to five times that of gasoline. However, diesel engines are main contributor to environmental degradation. Due to growing awareness about climate change and depletion of fossil origin fuels, exhaustive research is carried all around the globe to evaluate the suitability of the variety of alternative fuels. Biodiesel, which is carried all around the globe to evaluate the suitability of the variety of alternative fuels. Biodiesel, which is produced from the variety of vegetable oils and animal fat through transesterification, has a lot of technical advantages over fossil fuels such as lower overall exhaust emission and toxicity, biodegradability, derivation from the renewable and domestic feedstock, negligible sulfur content.**

Biodiesel has a comparable energy density, cetane number, heat of vaporization and stoichiometric air-fuel ratio with that of the diesel fuel. Non-edible oil derived from Kusum (Schleichera Oleosa), an oil-bearing plant, is a potential feedstock for biodiesel production. In the present study, various physio-chemical parameters of the Kusum oil have been studied to evaluate its suitability as a potential feedstock for biodiesel production. The fatty acids are 40% whereas saturated fatty acids are around 53%. In the light of the exhaustive study, it can be that Kusum oil is a promising feedstock for biodiesel production for use as a fuel to improve its commercial viability.

Index Terms - Transesterification; Non-Edible Oil; Diesel Engine; Kusum Oil; Biodiesel; Alternative Fuel

INTRODUCTION

World Energy Demand is increasing everyday due to the expanding urbanization, better living standards and increasing population. At a time when society is becoming increasingly aware of the declining reserves of fossil fuels beside the environmental concerns, it has become apparent that renewable fuels are destined to make a substantial contribution to the future energy demands of both developed and developing nations. It is known that the remaining global oil resources shall be sufficient to meet demand up to 2030 as per estimates of IEA [1]. There is, therefore, a demand to explore alternative fuels motivated by the reduction of the dependency on the fossil fuels due to limited resources. Amongst the variety of alternative fuels, biofuels have a distinctive advantage and concept of using biofuels in Diesel Engines is not a new concept and it demonstration was carried by "Rudolf Diesel" at the world Exhibition in Paris in 1900 by using peanut oil as fuel. However, due to abundant supply of Petroleum Diesel, research on use of biofuels was not seriously pursued [2]. It received attention only recently when it was realized that petroleum fuels are dwindling fast and environment friendly renewable substitutes must be identified. In the recent years, serious efforts have been made by several researchers to use vegetable oil derived fuels in existing diesel engines, however, use of straight vegetable oils is restricted in diesel engine due to some unfavorable physical properties, particularly their viscosity [3]. Due to higher viscosity, the straight vegetable oil cause poor fuel atomization, incomplete combustion and carbon deposition on the injector and valve seats resulting serious engine fouling. It has also been found that when direct injection engines are fueled with neat vegetable oil, injector gets choked up after few hours and lead to poor fuel atomization, less efficient combustion and dilution of lubricating oil [4]. The best route is to convert vegetable oil into its ester known as biodiesel through the process of transesterification. Currently, edible oils as feedstocks for biodiesel production (more than 95%) [5]. However, use of edible oils as feedstocks for biodiesel production has an influence on the global oil supply resulting in higher prices. Thus, focus should be shifted to non-edible resources, which are not used for human consumption and could grow in the barren lands. Oils from these resources are, as a rule, unsuitable for human consumption due to the presence of toxic compounds [6]. Non-edible vegetable oils which are known as The Second Generation Feedstocks can be considered as promising substitutions for the traditional edible food crops for the production of biodiesel. However, as a serious drawback, most non-edible oils contain a high content of free fatty acids (FFA), which increases the biodiesel production cost [7].

The objective of this paper is to evaluate the scope and potential of Kusum Oil as a promising feedstock for biodiesel production and also to consider the important physio-chemical properties of Kusum Oil for its modification into biodiesel.

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The vegetable and animal derived feedstocks used to produce biodiesel are emerging in recent years as the fourth category of growing interest because of their high oil content and rapid biomass production [8] Different kinds of edible oils, depending upon the climate and soil conditions, are being used as the main conventionally feedstocks for biodiesel production such as rapeseed oil in Canada, sunflower oil in Europe, Soybean oil in US, Palm Oil in South-East Asia, coconut oil in Philippines, etc. However, as already highlighted non-edible plant oils are becoming very promising alternative feedstocks for biodiesel production because of large demand for edible oils than that of fossil fuels and the lower cost of non-edible oil plant cultivation. However, there will always be a competition between edible and non-edible oil bearing plants and when deciding which type of oil crops should be grown, in addition to profits, their impact on the environment should also be taken into account [9]. There is a large no. of oil plants that produce non-edible oils [10]. However, efforts need to be made to exploit the under-utilized feedstock.

BIODIESEL PHYSICAL AND CHEMICAL PROPERTIES

Some of the important physio-chemical properties of different vegetable oils and mineral diesel fuel are summarized in Table 3[6-7]. The biodiesel has properties different from diesel and some of the main differences are mentioned in the table 3.

In Indian context, only such plant sources can be considered which is essentially non-edible oil and can be grown on a large scale on wastelands. Moreover, some plants and seeds in the country have high medicinal value; as such, considering the use of oil from these plants as diesel engine fuel may not be a viable and wise option. With all the above options, trees or crops in India that can be considered as substitute for diesel fuel are the following [10];

- Schleichera Oleosa or Kusum
- Ricinus Communis or Castor
- Madhaca Indica or Mahua
- Jatropha Cuncas or Ratanjat
- Pongamia Pinnata or Karanja
- Azadinachta Indica or Neem
- Hevea Brasiliensis or Rubber Seeds
- Calotropis Gigantia or Ark
- Euphonbia Tirucalli or Sher
- Onizya Sativa or Rice Bran Oil

Among these potential plant alternatives, Schleichera Oleasa or Kusum has the immense potential as Biodiesel feedstock.

FEEDSTOCK AND PRODUCT CHARACTERISTICS

Types of feedstocks for Biodiesel production

Feedstocks for biodiesel production can be traditionally categorized into three main groups [11]; vegetable oils(edible and non-edible), animal fats and waste cooking oils(used oily materials). Additionally, algal oils have been Known as triacylglycerides (TAGs), or more simply triglycerdes. In general, biodiesel feed stock can be categorized into four groups: oilseeds(edible or indebile oil), animal fats, waste materials and algae as summarized in table 1.

Fig .1 Life cycle of Biodiesel production

Table 1: Feed stocks categories of biodiesel production [8]

Category	Classification	Feed Stock
Oil Seeds	Edible	C: Soybean, rapeseed, sunflower, palm, coconut, olive
		A: Flash fax, safflower, seasame, marula, pumpkin, ricebean
	Inedible	A: Jatropha, Karanja, Mahua, linseed, Rubber seed, Cotton seed, Neem, Carnelian, tobacco, polanga castor, kusum
Animal Fat	Inedible	C: beef tallow, pork land
		A: waste salmon, melon bug, sorghum bug, chicken fat
Waste Materials	Inedible	C: Cooking oil, frying oil
		A: Vegetable oil soap stock, acid oil, tall ail, dried distiller’s grain(DDG), pomace oil
Algae	Inedible	

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**G- Conventional fuel; A- Alternative fuel

Table-2: Cultivated area of oil seed plants [9]

Country	Oil seed area million ha	% of world seed area	Yield tons/ha
USA	35.98	18.94	2.10
India	32.0	16.84	0.89
China	28.01	14.74	1.84
Brazil	22.51	11.85	2.45
Argentina	16.24	8.55	2.32
Canada	5.86	3.09	1.55
France	1.85	0.97	2.69
Germany	1.31	0.69	2.83
Italy	0.31	0.16	2.23
Russia	5.54	2.86	1.00
Pakistan	3.59	1.89	1.05
UK	0.54	0.28	3.33

Indian Bio-fuel sector: Overview

On the oil seed map of the world, India occupies a well-known position with regard to area under cultivation; however yield is lowest among all other countries (table 2). India accounts for 8.5% of world oil seed production.

It is quiet important in India to grow oilseed trees. The waste land (70 million ha) in the country could be made green and produce oil and bio-residues for various uses. Growing oil highways and in backyards all over nation will improve the availability of these oil. Seed-oil can be extracted from a variety of plants and oilseeds.

FFA of kusum oil

FFA (Free fertly acid) present in oil is 5%- 11%. Iodine value is 215-220 and total fatty acid content is 91.6%. Table 4 shows the fatty acid composition of kusum oil reported by different researchers. The oil can be used as substitutes of diesel but the greatest difference between kusum oil and diesel oil is viscosity. The high viscosity of this kusum oil may contribute to the formation of carbon deposit in the engines, incomplete combustion and results in reducing the life of engine[23].

Table 4: Characteristics of fatty acids in kusum oil

S.No.	Name of fatty acid	Chemical name of fatty acids	Chemical name	Formula	% value [23]	% value [22]	% value [21]
1	Capric		10:0	-	0.2	-	-
2	Lauric	Dodecanoic	12:0	$C_{12}H_{24}O_2$	0.3	0.31	-
3	Myristic	Tetradecanoic	14:0	$C_{14}H_{28}O_2$	0.3	15.54	0.01
4	Palmitic	Hexadecanoic	16:0	$C_{16}H_{32}O_2$	8.0	10.35	7.59
5	Stearic	Octadecanoic	18:0	$C_{18}H_{36}O_2$	2.3	11.11	-
6	Oleic	Octadecanoic	18:1	$C_{18}H_{34}O_2$	42.6	27.08	49.69
7	Linoleic	Octadecadienoic	18:2	$C_{18}H_{32}O_2$	4.5	6.14	5.56
8	Arachidic	Eicosanoic	20:0	$C_{20}H_{40}O_2$	21.3	15.79	-
9	Eicoseronic	Eicosenonic	20:1	-	15.2	0.08	29.54
10	Behenic	Docosanoic	22:0	$C_{22}H_{42}O_2$	1.5	0.01	1.14
11	Erucic	Cis-13-Docosnoic	22:1	$C_{32}H_{42}O_2$	1.9	-	1.22
12	Palritoleic		16:1	-	1.3	-	1.8

1 or 2 irregular ellipsoidal slightly compressed seeds with a thick brown seed coat. The seeds are brown irregularly elliptic, slightly compressed, oily, enclosed in a succulent aril. The brown seed coat is brittle and breaks at a slight pressure to expose a 'U' shape kerned as shown in figure 2. The leaflets are 2 to 4 pairs, elliptic or elliptic oblong, coriaceous margins entire and apex rounded. The flowers are minute, yellowish green; male or bisexual, fascicled in spike like auxilary racemes 7.5 to 12.5 cm long. The wood is suitable for fuel wood and charcoal. It is host true for best grade lac insects [11].

Application of Kusum oil

The oil is better in taste thus it is not considered to be edible. In India, the oil is used generally for soap making. It is traditionally used as medicine for the cure of itch, acne, burns other skin trouble rheumatism (external massage), hair dressing and promoting hair growth. Oil is also for culinary, lightning purposes and lubrication.

Physio-Chemical Property of Kusum Oil

The oil content is 51%-62% but the yields are 25%-27% in the village ghanis (oil mills) and about 36% oil in expellers. Kusum oil is yellowish brown semi-solid, with faint odour of bitter almonds, when allowed to settle down, light coloured solid fat separates out and settles down. It contains only 3.6% to 3.9% of glycerin while normal vegetable oil contains 9-10% glycerin. Lower energy density, necessitating greater mass of fuel to be injected in order to achieve the main same engine power output.

Ultra low natural sulfur content(Considered a soot precursor), biodiesel having practically zero sulfur content, and animal based ones are extremely small; however this advantage

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seems to gradually fades owing to the continuous desulfurization of the petroleum diesel fuel[12].

Higher cetane number (represents the ignitability of fuel, with higher CN leading to shorter ignition delay); cetane number decreases as the number of double bonds increases, i.e. as the methyl ester becomes more increases, i.e. as the methyl ester becomes more unsaturated. Highly saturated esters such as those derived from coconut, palm, tallow and used cooking oil have the highest cetane numbers.

Table 3: Fuel properties of non edible oils

Properties		Jatropha [2,10-12]	Karanja [2-4]	Mahua [2-4]	Castor [9,10, 22]	Polanga [2,9,10]	Kusum [3,19-23]	Diesel [1,2,3]
Density kg/m^3,40^{0}C		901-940	870-960	865-950	956	896	860	820-845
Viscosity mm^2/s,40^{0}C		24.5-52.56	27.8-56	24.6-37.6	98-130	71.9	40.36	2.0-2.7
Flash point ^{0}C		180-280	198-263	212-260	447	221	225	45
Pour Point ^{0}C		-3 to 5	-3 to 6	12 to 15	-15 to 2	-	-	-20 to 5
Cloud Point ^{0}C		8-10	13-15	12	4-10	-	-	-
Cetane number		33.7-51	45-67	43.5	36	-	47	45
Calorific Value (mJ/kg)		38.2-42.15	34-38.8	35.6-38.9	32-34	38-39.5	38-38.5	44-46
Oil content wt%	Seed	20-60	25-50	35-50	45-50	65	50-53	-
	Kennel	40-60	30-50	50	50	40-70	50-65	-
FFA wt%		13.5-14.4	30-50	27-35	30-40	44	5-11	-

- Higher density (volumetrically-operating injectors inject greater mass of biodiesel than conventional diesel fuel.
- Higher bulk modulus of compressibility (at least in parts, owing to the pressure of oxygen in the fuel structure which creates a permanent dipole moment in the molecule)
- Higher flash point (is a measure of temperature to which a fuel must be heated such that the mixture of vapor and air above the fuel can be ignited); but due to this neat biodiesel is thus much safer than diesel in this regard.

In the present study, potential suitability of Kusum or Schleichera oleosa seed oil is evaluated as biodiesel feedstock.

KUSUM (SCHLEICHERA OLEOSA)

The botanical name of Kusum is Schleichera oleosa and the potential of Kusum oil is around 66,000 tons per year in India, out of which 4000 to 5000 tons are collected [12]. It is a medium to large sized, evergreen dense tree growing to 35 to 45 feet in height. It mainly occurs in sub-Himalayan tracks in the Northern and Central parts of eastern India. The flowers come from February to April and yields fruit in June and July. The one or two almost round seeds some 1.5 cm in diameter and weighing between 0.5 and 1.0 gm. The weight of 1000 seed is 500-700gm. The fruits are berry, globose or ovoid, and hard skinned berry with a pointed tip and size is (1.25-2.50)x(1.1-1.8) cms.

CONCLUSION

Biodiesel has many positive attributes as far as India is concerned and need to identify an exploited feed-stocks for biodiesel production is gaining momentum. The under utilized or un exploited feed-stocks such as Kusum or Schleichera oleosa has the enormous potential for India to improve the balance of trade, betterment of environment, rural empowerment, job creation and energy security. The socio-economic condition in the villages could be improved through large scale cultivation of this plant on the degraded barren land. Moreover, it can be grown without competing with annual food crops. It has very high oil content as compared to other oilseed crop and oil extraction is possible in villages using ghanis or expellers. The fatty acid profile suggests that unsaturated fatty acids are 40% whereas saturated fatty acids are around 53% suggesting that it shall brave better oxidation stability. Use of Kusum oil as a feedstock for biodiesel production has large positive attributes for India and concentrated efforts need to be made by all stake holders for large scale cultivation of Kusum in India for production of biodiesel at a competitive price.

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