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JATROPHA OIL: AN ECO-FRIENDLY SUSTAINABLE BIO-FUEL SOURCE

MAMTA SAHU, V.K.GOUR AND SWATI GUPTA

Department of Plant Breeding & Genetics J.N. Krishi Vishwa Vidyalaya, Jabalpur 482 004, M.P., India

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ABSTRACT

***Jatropha curcas* belonging to family Euphorbiaceae, a perennial plant produces seed with 31-37 percent of oil, which can be combusted as fuel without being refined. This fuel known as the process of transesterification can produce bio-diesel. Jatropha plant is grown in marginal and poor soil with minimum cultural practices or in wastelands with low fertility, rockiness, and shallowness of soil. Besides higher cetane number, oil reduces emission of carbon monoxide by 44 percent, sulphates by 100 percent and ozone forming potential by less than 50 percent. Through Jatropha cultivation, not only bio-diesel can be obtained but also a tremendous opportunity will be there for employment generation in an agricultural country like India. This paper provides some inputs to show the importance of bio-fuel to combat pollution problems and solve fuel crisis.**

INTRODUCTION

Fossil fuels have been the main source of energy during the past two centuries and infact, have been the backbone of industrial growth during these years. Unfortunately, these fossil fuels are non-renewable. Increasing trends of consumption of these fuels would soon result in the depletion of reserves. It has led the scientists and researchers to search for new alternatives, assume high importance not only in terms of rescuing the national economy and development activities but also in the context of reducing pollution. One of such alternatives is biofuels, which have emerged as the most potent source of energy to reduce the current dependence on fossil fuels. Bio-diesels are derived through a simple transesterification process from vegetable oils, renewable lipids, rendered animal fats or any combinations of these ingredients.

The concept of using vegetable oil as an engine fuel is not new. It dates back to 1900 when Rudolf Diesel developed the first engine to run on peanut oil and demonstrated it at the World Exhibition in Paris. Soon after that, the petroleum industry witnessed rapid development and cheap "diesel fuel" were available for powering modified "diesel-engine". Thus, the clean vegetable oil was forgotten as a renewable source of power, re-emerged again after the onset of oil crisis in early 1970's. The scientific investigations and experimentations in recent years, have established that this renewable source is efficient as petroleum diesel in powering diesel engines without any substantial modification to the existing design (Biswas, 2003).

Corresponding author : Email : egreen@rediffmail.com

Concept of bio-diesel

Bio-diesel is defined as the mono-alkyl esters of fatty acid derived from vegetable oils or animal fats. In simple terms, bio-diesel is the product obtained when a vegetable oil or animal fat is chemically reacted when an alcohol to produce fatty acid alkyl esters. A catalyst such as sodium or potassium hydroxide is required. Glycerol is produced as a co-product. The approximate proportion of the reaction is:

100 kgs crude oil +24 kgs methanol
2.5 kgs NaoH $\longrightarrow$ 100 kg Bio-diesel + 26 kg glycerine

For each tone of bio-diesel, 100 kg of crude glycerine is simultaneously produced in the process.

Bio-diesel production

The main reaction for converting oil to bio-diesel is called transesterification. It is the process of reacting a triglycerido molecule with an excess of alcohol in the presence of a strong base catalyst, such as KOH, NaOH, $NaOCH_3$ etc to produce fatly esters and glycerol. The chemical reaction with melhanol is shown schematically below:

CH_2OCOR, Catalyst $RiCOOCH_3$ CH_2OH
$CHOCOR_2 + 3CH_3OH \longrightarrow R_2COOCH_3$
$+ CHOH$ CH_2OCOR_3 OH R_3COOCH_3 CH_2OII *(Triglycerides) (Metanol) (Bio-Diesel) (Glycerol)*

Ri,R_2,R_3 are the fatty acid chain

International scenario

World bio-diesel production is estimated to have increased from modest 50,000 tonnes in 1991 to about 29,00,000 tonnes. Out of Ihe world total vegetable oil production of about 62 million tonnes, about 3 lo 5 million tonnes are likely to be used as bio-diesel (Choo Yuen, 2002) The developed country viz Germany, France and Italy makes bio-diesel from rapeseed oil; USA, Brazil & Argentina from Soyabean; Malaysia & Indonesia from palm oil and developing economies like India, China and Phillipincs are venturing to develop bio-diesel from Jatropha. Annual production of biodiesel fuel in the world are as in Table 1.

Table 1. Annual production of bio-diesel fuel in the world

Countries (Thousand kiloliters)	Annual production	Sources
Austria	30	
Belgium	80	
France	390	Raw Materials
Germany	800	are mainly
Great Britain	20	vegetables oil
Italy	240	extracted from
Sweden	8	cultivated
Denmark & Ireland	2	rapeseed,
United states	80	soybeans etc
Canada	2	
Malaysia	10	
Japan	2	
India	2	Mainly from Pungam oil

Source : Approach to bio-diesel fuel production project-Bio-diesel fuel.

Indian scenario

India has great potential for production of bio-fuels like bio-ethanol and bio-diesel 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 tones per annum. Wild crops cultivated in the wasteland also form a source of bio-diesel production in India and according to the Economic Survey of Government of India, 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 bio-diesel in a large scale.

In our country, oils extracted from seeds of different species have been traditionally used as a source of energy, lightening and heating. Gradually, these oils were used for more valuable purposes such as production of soaps, candles, cosmetics and pharmaceuticals. In the past, use of these oils as a substitute for diesel, was not considered economically viable as diesel was available at a cheaper price but now. with a steep hike in the international prices of crude petroleum and its products and also due to increasing judicial intervention to mitigate pollution caused by emissions from diesel-driven automobiles, there is a growing demand and urgency to use vegetable oils as a substitute for diesel. As a result, several initiatives have been made by research institutions, government agencies and automobile industry to promote the production and use of bio-fuels. Indian railways have taken an important initiative to successfully test run Jan Shatabadi Express from Delhi to Chandigarh exclusively on bio-diesel produced from the oil obtained from Jatropha seeds. Mahindra & Mahindra have also conducted large scale trials of operating their tractors on bio-diesel. Mercedes Benz is sponsoring Jatropha plantation with a commitment to use bio-diesel run their cars.

According to an estimate (agroindia,2003), the country has potential to produce about 30 lakh tones of vegetable oils from non-traditional oilseeds, oil cakes, minor oilseeds and oilseeds of tree origin and cotton seed. The potential tapped, however is only 13.8 lakh tones mostly from non-traditional sources. GOI has chosen bio-diesel produced from oil-bearing seeds of Jatropha as a substitute for HSD (high speed diesel) under recently launched National Mission on Bio-diesel (NMB) laying major emphasis on its planned cultivation and R & D.

Advantages of Bio-diesel

1. Bio-diesel is eco-friendly, bio- degradable, non-toxic and essentially free of sulphur, lead and aromatics.
2. Domestically produced renewable source reducing country's dependence on imported fuel thereby saving precious foreign exchange.
3. Biofuels have high cetane number than petrol/diesel resulting in higher engine performance. Tests have shown that bio-fuels have better fuel consumption, horsepower, torque and haulage rates than the conventional diesel.
4. Bio-diesel has superior lubricating properties, increasing the functional efficiency of engines.
5. Bio-diesel have higher flash point making them safer to store.
6. Bio-diesel molecules are simpler hydrocarbon chains, containing no sulphur or aromatic substances associated with fossil fuels.
7. Bio-fuel contain more oxygen (upto 10%) which ensures complete combustion.
8. Bio-diesel completely eliminate life cycle carbon dioxide and sulphate emission. They also reduce emission of particular matter by 40%, unburnt hydrocarbons by 60%, carbon monoxide by 44%, polycyclic aromatic hydrocarbons (PAHs) by 80% and the carcinogenic nitrated PAHs by 90%.
9. The use of bio-diesel complements the working of the catalyser and can help a current EURO I motor attain the EURO III standards.
10. Using 100% Bio-diesel (B100) will further reduce emissions and carcinogens.

Sources of Bio-diesel

Oil can be extracted from a variety of plants and oilseeds. Under Indian condition only such plant sources can be considered for bio-diesel production which are not edible oil in appreciable quantity and which can be grown on large-scale on wastelands. Moreover, some plants and seeds in India have tremendous medicinal value, considering these plants for bio-diesel production may not be a viable and wise option. Considering all the above options, probable bio-diesel yielding trees in India are :

- *Jatropha curcas* or Ratanjot
- *Pongamia pinnata* or Karanj
- *Calophyllum inophyllum* or Nagchampa
- *Hevea brasiliensis* or Rubber seeds
- *Calotropis gigantia* or Ark
- *Euphorbia tirucalli* or Shcr; and

Table 2. Annual Production of Non-edible Oil Seeds in India

Type	Production (MT)	Oil %
Neem	500	30
Karanj	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

Source: Interim Report of Auto Fuel Policy.

Table 3. Physical and Chemical properties of oils

Samples	Flash Point© (CST)	Kinetic Viscosity (Calories/gram)	Calorific value (C)	Cloud Point (mgKOH/g)	Total Acidity
Pongamia oil	290	48.48	8992	18	5.07
Neem oil	290	53.17	8998	18	5.97
Mahua oil	360	45.36	8864	25	1.49
Jatropha oil	50	50.73	9470	18	5.00
Groundnut oil	326	87.80	9399	10	2.00
Coconut oil	290	53.40	9890	12	2.79
Cottonseed oil	250	40.02	10266	13	3.5
Castor oil	300	190.00	10209	5	3.33
ASTM Standards	100	6.00	9760	13	0.8

- *Boswellia ovalifololata.*

Of all the above prospective plant candidates as biodiesel yielding sources, Jatropha curcas stands at the top. The comparision of Jatropa oil with other vegetable oil is furnished in Table 3.

Jatropha as a best source of bio-fuel

Jatropha curcas has been identified as the best species for bio-fuel production among all the TBOs because of the follov ing reasons-

1. Oil yielding per hectare is one of the highest among the TBOs, although presently, there is lack authentic information on the seed yield of various TBO species. The largest Jatropha cultivation in India was in Nasik district of Mahand the the average yield in this region has been found to be in the range of 1 to 1.5 tons/ha/year. There are some reports in which yields of 10 tons/ha/year have also been claimed but these figures appear to be unrealistic and therefore, unreliable in rainfed conditions.
2. Jatropha may starts fruiting in the very first year of its planting, although thr yield is low. It starts giving seed in a maximum period of two years. Thjerefore, the gestation period is very short makingthe cost benefit analysis of its planting attractive.
3. Jatropha can be grown in a wide range of climate and edaphic conditions. It cvan be grown in the areas of low rainfall (unto 200 mm per year) also, although yet in high rainfall and irrigated areas. It can be grown emeytic soils also.
4. The plant is undemanding in soil type and does not required tillage. It can grow even on alkaline soils.
5. Jatropha is easy to establish, grows relatively quickly and is hardy. Animals do not browse it.
6. Jatropha seeds can be collected easily as they are ready to be plucked before the rainy season and the plants are not very tall.
7. Its propagation is quite easy. It can be established from seeds, seedlings and vegetatively from cuttings. Use of branch cuttings for propagation is easy and result in rapid growth.
8. It can be raised on all sorts of lands like lands developed on watershed basis, lands of low fertility, marginal, degraded, fallow, waste and other lands such as along the canals, roads. Railway tracks, field bunds etc. It acts as an excellent live hedge or a boundary fence when raised on field bunds.

General background

Jatropha is a perrinial plant belonging to the family called Euphorbiaceae. It is termed as physic-nut or purging nut in English, Ratanjyot in Hindi, Kattamanakku in Tamil, Jepal in Gujrati and Kanana-randa in Sanskrit. The center of origin of the crop is Mexico and Central America. It has been introduced to Africa and Asia by the Portuguese as an oil yielding plant and is now cultivated throughout the world. In India, Central and Western parts like Gujarat, Rajasthan, Madhya Pradesh, Maharashtra and Southern states like Tamil Nadu and Andhra Pradesh are the leading states producing Jatropha. The plant which flowers during the rainy season , produces yellowish green flowers in racemose inflorescence.The average ratio of male and female flower in the infloresence is 29:1. It is a small tree or shrub with smooth grey bark, which excudes whitish coloured watery latex when cut. Normally the plant is 3-5 meter in height but upto a height of 8 meter has been found under favourable conditions. The fruits are 2.5 centimeter long, black and 2 to 3 halved. Fruits mature by September-October when the capsule changes from green to yellow in colour. It has nearly 420 fruits and 1580 seeds per kg. respectively.

The genus Jatropha has 476 species and distributed throughout the world. Among them 12 species are recorded in India. The species Jatropha curcas is a promising one with economic seed yield and oil recovery. The oil from Jatropha curcas can be used as bio-diesel blend up to 20%. However, the refined oil is a qualified neat biodiesel. The plant flowers a year after planting and the economic yield is obtained from 4^{lh} year onwards.

Jaropha Oil

Jatropha. the wonder plant, produces seeds with 31-37 percent of oil content, which can be combusted as fuel without being refined. It bears a clear smoke-free flame. In the CSIR Institute (CSMCRI) Jatropha Methyl Ester (JME) fulfilled most Euro-4 emission norms in its non-blended form. Bio-diesel's phosphorus and sulphur contents were found to be lower than those of fossil diesel and its cetane number, a measure of ignition quality was higher than the standards required in some developed countries. The oil gave the car a mileage of 15.5 km per litre in test condition and about 13.5 km per litre in normal condition, which was at per with the mileage from the fossil diesel. Using a base price of Rupees 6 per kg for Jatropha seed and a standard yield of one litre of JME from 3.5 kg of Jatropha seed, the scientist

have calculated a rough price of Rupees 24 per litre of bio-diesel, comparable to fossil diesel. From the second year after planting, the plant starts yielding but maximum yield can be obtained from the fifth year onwards of planting upto 40-50 years. From one hectare of land around 3.5-3.75 tonnes of oil can be obtained.

Besides high cetane number, the oil reduces emission of carbon-monoxide by 44%, sulphates by

Table 4. Chemical composition of Jatropha oil

S.No.	Items	Value
1.	Acid value	38.2
2.	Saponification value	195
3.	Iodine value	101.7
4.	Viscosity (31°C) fatty acid	40.4
5.	Palmitic acid %	4.2
6.	Stearic acid %	6.9
7.	Oleic acid %	43.1
8.	Linoleic acid %	34.3
9.	Other acids %	1.4

Table 5. The comparison of properties ofJatropha oil and standard specifications of diesel oil

Specification	Jatropha oil	Diesel
Specific gravity	0.9186	0.82/0.84
Flash point	240/1 10 °C	50 °C
Carbon residue	0.64	0.15 or less
Cetane value	51.0	50.0 up
Distillation point	295 °C	350 °C
Kinematics Viscosity	50.73 cs	2.7 cs up
Sulphur %	0.13%	1.2 %or less
Calorific value	9 470 kcal/kg	10170kcal/kg
Pour point	8°C	10°C
Colour	4.0	4 or less

Table 6. Physical and chemical properties of diesel fuel and Jatropha oil

Property	Jatropha Oil	Diesel Oil
Viscosity (cp) (30 °C)	52.6 (5. 51)[2]	3.60
Specific gravity (15 °C/4°C)	0.917/0.923 (0.881)	0.841/0.85
Solidfying Point (°C)	2.0	0.14
Cetane Value	51.0(38)	47.8 .59
Flash Point (°C)	110/340	80
Carbon Residue (%)	0.64	< 0.05. < 0.15
Distillation (°C)	284 . 295	< 350. < 370
Sulfur (%)	0.13 .0.16	<1.0. 1.2
Acid Value	1.0.38.2	—
Saponification Value	188. 198	—
Iodine Value[3]	90.8. 112.5	—
Refractive Index (30°C)	1.47	—

100%, unburnt hydrocarbon by 68% and the ozone forming potential of Bio-diesel is 50% less then the fossil diesel.The neat Bio-diesel was also tried in a high-powered non-automobile engine without modifying the Engine with satisfactory result. Transesterifica-tion process also gives byproducts like glycerine and oilcake. The oilcake is a good source of organic manure which contains about 38% protein. Some cost of transterification can be met by seeing oil cake and glycerine on an attractive price.

Chemical composition of Jatropha oil

Jatropha curcas contains 30-35% oil. The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids. There are some chemical elements in the seed, which are poisonous and render the oil unfit for human consumption. The oil is renewable and safe source of energy. It is viable alternative to diesel, kerosene, LPG, furnance oil, coal and fuel wood. Oil is also used in resins, polish, paints, soap and candle industries. The seeds contain protein 18%, fat 38%, carbohydrate 17%, fibre 15.5%. The chemical composition of Jatropha curcas oil is given below-

It is significant to point out that, the non-edible vegetable oil *of Jatropha curcas* has the requisite potential of providing a promising and commercially viable alternative to diesel oil since it has desirable physicochemical and performance characteristics comparable to diesel. Cars could be run with *Jatropha curcas* without requiring much change in design.

Jatropha oil resulted in a slightly reduced thermal efficiency as compared to diesel. This renewable fuel's high cetane values, very low sulfur content and high oxygen content give it excellent combustion properties. It was reported that the ignition delay & combustion duration are increased with both Jatropha oil & methyl ester of Jatropha oil as compared to diesel. Lower heat release rates are found with Jatropha oil & methyl ester of Jatropha oil as compared to diesel during the pre-mixed combustion phase.

The combustion of bio-diesel releases only the amount of COi that the plant removed from the atmosphere when it was growing. Only the amount of energy used for the cultivation, harvesting and transport of the plants plus the energy needed to produce bio-diesel affects the CO2 balance. And in principle, it is possible to significantly reduce that energy figure.

Limitation

The Jatropha also suffers from certain limiting factors, which need to be kept in mind while dealing with the species. These are as follows:

1. Jatropha cannot be grown on waterlogged lands and slopes exceeding 30 .
2. The ideal climatic condition for Jatropha can be summarized as annual rainfall not exceeding 600 mm in moderate climatic condition, 1200 mm in hot climatic zones and soil pH less than 9. The atmospheric temperature should not fall below 0°C as the plants are sensitive to ground frost that may occur in winters.
3. Jatropha seeds are hard and possess toxicity.
4. The golden flea beetle (podgarica spp.) can harm particularly on young plants.
5. Jatropha is also host to the fungus 'frogeye' (Cercospora spp) common in tobacco.

CONCLUSIONS

Biodiesel is an environmental friendly alternative to the fossil fuel and hold immense potential to mitigate the future energy needs of the country and also to impart economic prosperity in the poor and backward areas of the country. In India, our domestic production of fuel is simply not able to keep pace with the ever-growing needs, compelling us to depend heavily on imports. With about 70% of domestic demand for fuel to be met from imports, there is a huge outflow of valuable foreign exchange. Besides, the increasing use of fossil fuel has also been resulting in such seriously deleterious problems as Green House Effect affecting the entire humanity. It is therefore, impending that a safe alternative is explored and exploited. And Jatropha presents a most viable option.

Jatropha plantation has been identified as a most suitable option for the production of bio-fuels utilizing non-edible sources. There is clear indication that Jatropha cultivation can make a significant contribution to the bio-fuel production and in sustainable development of the country, as the rapidly increasing consumption and consequent depletion of reserves clearly show that the end of fossil fuel is not much far away.

Jatropha is thus unique among renewable energy sources in terms of the potential benefits that can be expected to result from its widespread use. Its cultivation is technologically simple and requires comparatively low capital investment .The large scale cultivation of jatropha showed strongly target the total degraded land (which is about 296mha) that requires treatment before food production is possible on them again . On the whole, this crop is gaining momentum as **"Future Fuel".** There is some belief that use of Jatropha oil as fuel may bring down the pollution level. It has been successfully used to work any kind of engine. It can be used to run generators as well. It is diluted with 80% petrol-diesel. Its greatest merit is that it is bio-degradable & non-toxic & therefore eco-friendly.

REFERENCES

Dilip Biswas, 2003. Development of Biofuels, CPCB, New Delhi. From http:7www.cpcb.nic.in.

Choo Yuen May, 2002. Bio-diesel: Status of Global Bio-diesel Dev and Future Trend, In ICS-UNIDO Workshop on Catalytic Technol for Sustainable Industrial Process Utilizing Crop Derived Renewable Raw Materials, Dec 17-19

Approach to biodiesel fuel production project- Biodiesel fuel. *Bulletin,* Mechanical Engineering Department, Southern Railways, 2p.

Agroindia, 2003.http://www.agroindi.org/agroindia/oilseeds_extractions/vegoilindia.htm