# Biodiesel production from *Jatropha curcus* oil

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**Abstract**— *Jatropha curcus* seeds produce non-edible oil, which was considered as an ideal feed stock of biodiesel production. In this study, *Jatropha curcus* was cultivated by seedlings in an experimental farm at Faculty of Science, Damietta University. One hector accommodates 6667 *Jatropha* trees, and produced 1390 kg dry seeds. To avoid the use of solvents, for economic feasibility, and preventing environmental pollution, a mechanical olive oil mill was used to squeeze the seeds. A sample of *Jatropha* seeds (175.74 g) was squeezed to give 28.42 g oil (16.17% yield). Based on the high free fatty acids% (96.47%), we preferred the acid catalyzed esterification to produce the biodiesel using commercial methanol and HCl. The methyl esters (biodiesel) yield was $>$ 95%. The composition of both the oil and the biodiesel were determined by GC/MS. The main components were linoleic acid (79.16%) and palmitic acid (17.31%) in the oil; and methyl linoleiate (77.13%) and methyl palmitate (19.46%) in the biodiesel.
The chemical and physical properties of a biodiesel sample were tested, according to ASTM Standards, by Egyptian Petroleum Research Institute (EPRI), Nasr City, Cairo, Egypt. The conversion of *Jatropha* oil into the methyl esters (biodiesel), has lowered the kinematics viscosity, at, 40$^{o}$C, from 50.73 to 2.52, compared to 2.7 as a standard value for petroleum diesel. Flash point is specified in biodiesel to serves as a restriction of the amount of alcohol in biodiesel for safety measures in transportation and storage. In our study, the flash point of the methyl esters (biodiesel) was 302$^{o}$C. The cetane index of the methyl esters (biodiesel), a measure of the ignition quality, was found to be 58.82, compared to 51.0 and 50.0 as standard specifications of *Jatropha* oil and petroleum diesel, respectively, which was in agreement with the nil value determined to the parameters “BS & W, vol.%” (the volume percentage of base sediment and water), the “carbon residue, wt.%”, and the “ash content, wt.%”.

**Key words**—Biodiesel, *Jatropha curcus* seeds, linoleic acid, palmitic acid, kinematics viscosity, flash point, cetane index.



## 1 INTRODUCTION

Many renewable energy alternatives are being investigated “[1–3] as potential substitutes for the high-pollutant diminishing diesel fuel.

The high viscosity of vegetable oil represents an obstacle that affects its safe use in an indirect-injection, naturally aspirated and air-cooled engine for long periods of time. A way of reducing the viscosity of the vegetable oil fuel is to blend it with some proportion of diesel fuel by volume and/or pre-heat the vegetable oil before it is admitted to the combustion chamber [4].

To avoid the conflict between food security and biodiesel production, second generation biofuel has drawn much attention. From this sense, *Jatropha curcus* is widely considered as an ideal feed stock of biodiesel production. The properties of *Jatropha* crop and *Jatropha* oil are main consideration of policymakers to persuade *Jatropha* as a potential cradle of biodiesel.

*Jatropha* is believed to be native of South America, where its shrubs were spread in arid, semi-arid and tropical areas. *Jatropha curcas* is shrubs or small trees (up to 7-10 m high) that belong to Euphorbiaceae. Its bark papery, peeling, branches thick with viscid sap, sometimes becoming red and gummy. Yellow leaves are 5-lobed or entire, orate rounded, about 8.5 cm long and broad, glabrous; petioles about 11 cm long. Flowers are yellow-green; stamens 8, inner connate; disk deeply, 5-lobed. Fruits are scarcely lobed, ellipsoid capsules about 2.5 cm long, black; seeds 3. Flowers blossom in April; fruits ripe in May [5].

*Jatropha* curcas grows almost anywhere – even on gravelly, sandy and saline soils. It can thrive on the poorest stony soil. It can groweven in the crevices of rocks. The leaves shed during the winter months form mulch around the base of the plant. The organic matter from shed leaves enhance earth-worm activity in the soil around the root-zone of the plants, which improves the fertility of the soil [5].

Biodiesel is becoming prominent among the alternatives to conventional petroleum diesel due to economic, environmental and social factors. The quality of biodiesel is influenced by the nature of feedstock and the production processes employed. High amounts of free fatty acids in the feedstock are known to be detrimental to the quality of biodiesel [6].

The present work presents the results obtained from a project funded from Mansoura University as a feasibility study on the possibility of growing *Jatropha curcas* in the salty poor lands north delta, and its oil production, as well as its transformation to the methyl esters (biodiesel).

## 2 EXPERIMENTAL

### 2.1 Cultivation of *Jatropha*

Seedlings were produced by planting *Jatropha* seeds in polyethylene bags that were removed before planting in holes 30*30*30 cm in sandy soil. The shrubs were irrigated without any fertilization in an experimental farm of 135 m2, containing 90 Jatropha trees. Every tree has produced about 208.7 g dry seeds.

### 2.2 *Jatropha* oil production

An olive oil mill at Department of agricultural engineering, Faculty of Agriculture, Mansoura University, was used in squeezing *Jatropha* seeds. A sample of *Jatropha* seeds (175.74 g) was squeezed to give 28.42 g oil (16.17% yield).

### 2.3 GC/MS analysis of *Jatropha* oil

The *Jatropha* oil was analyzed by GC/MS, at the Central Laboratory of the Ministry of Agriculture, Al Bhooth, Cairo, using Agilent 6890 gas chromatograph equipped with an Agilent mass spectrometric column PAS-5ms (30 m x 0.32 mm x 0.25 um film thickness). Samples were injected under the following condition: Helium was used as carrier gas at approximately 1 ml /min, using pulsed split-less mode. The solvent delay was 3 min. and the injection size was 1.0 µl.The mass spectrophotometric detector was operated in electron impact ionization mode an ionizing energy of 70 eV. The masses were scanned from m/z 50 to 500. The ion source temperature was 230oC and the quadrupole temperature was 150oC. The electron multiplier voltage (EM voltage) was maintained at 1250 v above auto tune. The instrument was manually tuned using perfluorotributyl amine (PFTBA). The GC temperature program was started at 60oC then elevated to 280oC at a rate of 8oC / min. and 10 min.hold at 280oC. The detector and injector temperatures were set at 280 and 250oC, respectively. Wiley and Nist 05 mass spectral data base was used in the identification of the separated peaks. The analysis data were presented in table 1.

### 2.4 Conversion of *Jatropha* oil into biodiesel

An oil sample (20 ml) was mixed with commercial methanol (30 ml) and conc. HCl (2 drops) and was stirred at room temperature with a magnetic stirrer for 22 hrs (which was reduced in an optimization experiment to 30 min). The reaction mixture was mixed with about 30 ml tap water and extracted by CH2Cl2 (20 ml X 3) using a separatory funnel. The solvent was evaporated at 40oC, using rotary evaporator, giving the biodiesel (20.5 ml, > 95% yield). A sample was analyzed by GC/MS. The analysis data were presented in table 2.

### 2.5 Physico-Chemical Properties of Biodiesel

The chemical and physical properties of a biodiesel sample were tested, according to ASTM Standards, by Egyptian Petroleum Research Institute (EPRI), Nasr City, Cairo, Egypt. The data were tabulated in table 3.

## 3 RESULTS AND DISCUSSIONS

### 3.1 Cultivation of Jatropha

To achieve the project objectives, an experimental farm was constructed in the intended environment of the desert lands north Delta, at Faculty of Science, Damietta University. The farm was 135 m2, containing 90 *Jatropha* trees. Every tree produced about 208.7 g dry seeds.

Considering that one hector = 10000 m2, thus one hector acquires 90*10000/135= 6667 trees, and produces 6667*208.7 = 1391403 g, or approximately 1390 kg dry seeds, compared to 2-3.5 tons/ha/yr stated by Sarker [6], taking in consideration that the seed production/ha/yr reaches 4 folds after 2 years and 20 folds after 4 years [6].

### 3.2 *Jatropha* oil production

Although many researchers used n-hexane solvent extraction to obtain crude oil from the seeds [4], [7], [8], we preferred the oil production using a mechanical mill to squeeze the seeds, and to avoid the use of solvents for economic feasibility and preventing environmental pollution.

### 3.3 GC/MS analysis of *Jatropha* oil

Table 1 indicated that *Jatropha* oil is rich in free fatty acids (96.47%), comprising from linoleic acid (79.16%) and palmitic acid (17.31%), which was found to be in agreement with Okullo at al. [7].

### 3.4 Conversion of *Jatropha* oil into biodiesel

Usually the base catalyzed trans-esterification of the oil into the methyl esters (biodiesel) is used [7]. In this project, based on the high free fatty acids%, we preferred the acid catalyzed esterification to produce the biodiesel.

### 3.5 GC/MS analysis of biodiesel

Table 2 indicated the complete conversion into the methyl esters. Also the data showed that the major component was methyl linoleiate (77.13%), followed by methyl palmitate (19.46%).

The ability of biodiesel to meet ASTM D 6751 standard criteria is dependent on the fatty acid composition [9], [10]. Petroleum diesel is largely made of hydrocarbon with carbon chain length of 8 to 10 carbon atoms compared to *Jatropha* oil that contained fatty acids comprising of 16 to 18 carbon atoms (Tables 1 and 2). Cetane number which is a prime indicator of fuel quality for diesel engines is increased with increased carbon number [11].

**Table 1:** GC/MS analysis data of Jatropha oil

| Compound | MF | M Wt | Rt (min) | % |
|---|---|---|---|---|
| p-cymene | $C_{10}H_{14}$ | 134 | 6.31 | 0.68 |
| E,Z-2,4-decadienal | $C_{10}H_{16}O$ | 152 | 12.33 | 0.10 |
| E,E-2,4-decadienal | $C_{10}H_{16}O$ | 152 | 12.74 | 0.14 |
| hexadecane | $C_{16}H_{34}$ | 226 | 17.03 | 0.03 |
| 2-amino-N-isopropyl benzamide | $C_{10}H_{14}N_{2}O$ | 178 | 17.76 | 0.33 |
| octadecane | $C_{18}H_{38}$ | 254 | 19.76 | 0.09 |
| methyl palmitate | $C_{17}H_{34}O_2$ | 270 | 21.40 | 0.06 |
| palmitic acid | $C_{16}H_{32}O_2$ | 256 | 22.27 | 17.31 |
| methyl linoleate | $C_{19}H_{34}O_2$ | 294 | 23.45 | 0.30 |
| linoleic acid | $C_{18}H_{32}O_2$ | 280 | 24.55 | 79.16 |
| 2,3-dihydroxypropyl elaidate | $C_{21}H_{40}O_4$ | 356 | 27.68 | 0.25 |
| squalene isomer | $C_{30}H_{50}$ | 410 | 29.15 | 0.27 |
| squalene isomer | $C_{30}H_{50}$ | 410 | 30.69 | 0.41 |

### 3.6 Physico-Chemical Properties of Biodiesel

High viscosity is a major problem when using vegetable oil as an alternative fuel for diesel engines. Viscosity was reduced by heating, or blending the oil with diesel fuel. Chalatlon et al. [12] found that the viscosity of *Jatropha* oil decreased remarkably with increasing temperature and it became close to ASTM limits (ASTM D6751) for viscosity of biofuels when the temperature 100°C or more. Forson et al. [4] studied the performance of blends of diesel and *Jatropha* oil in a diesel engine. They found that the 97.4% diesel/2.6% *Jatropha* fuel blend produced maximum values of the brake power and brake thermal efficiency as well as minimum values of the specific fuel consumption. The 97.4%/2.6% fuel blend yielded the highest cetane number and even better engine performance than the diesel fuel suggesting that *Jatropha* oil can be used as an ignition-accelerator additive for diesel fuel. In our study, the conversion of *Jatropha* oil into the methyl esters (biodiesel), has lowered the kinematics viscosity, at, 40oC, from 50.73 to 2.52, compared to 2.7 as a standard value for petroleum diesel (Table 3).

**Table 2:** GC/MS analysis data of the biodiesel

| Compound | MF | M Wt | Rt (min) | % |
|---|---|---|---|---|
| isobutylaldehyde dimethyl acetal | $C_6H_{14}O_2$ | 118 | 6.17 | 0.04 |
| decyl acetate | $C_{12}H_{24}O_2$ | 200 | 11.76 | 0.01 |
| E,Z-2,4-decadienal | $C_{10}H_{16}O$ | 152 | 12.35 | 0.01 |
| E,E-2,4-decadienal | $C_{10}H_{16}O$ | 152 | 12.76 | 0.03 |
| 3-hydroxy-2,4,4-trimethylpentyl 2-methylpropanoate | $C_{12}H_{24}O_3$ | 216 | 13.68 | 0.02 |
| tetradecane | $C_{14}H_{30}$ | 198 | 15.55 | 0.01 |
| methyl laurate | $C_{13}H_{26}O_2$ | 214 | 15.97 | 0.01 |
| dimethyl azelate | $C_{11}H_{20}O_4$ | 216 | 16.40 | 0.02 |
| methyl myristoleate | $C_{15}H_{28}O_2$ | 240 | 18.46 | 0.05 |
| methyl myristate | $C_{15}H_{30}O_2$ | 242 | 18.83 | 0.13 |
| methyl pentadecanoate | $C_{16}H_{32}O_2$ | 256 | 20.15 | 0.07 |
| methyl palmitoleate | $C_{17}H_{32}O_2$ | 268 | 21.21 | 1.13 |
| methyl palmitate | $C_{17}H_{34}O_2$ | 270 | 21.61 | 19.46 |
| methyl Z-10-hepadecenoate | $C_{18}H_{34}O_2$ | 282 | 22.37 | 0.13 |
| methyl linoleiate | $C_{19}H_{34}O_2$ | 294 | 23.93 | 77.13 |
| methyl Z-13-eicosenoate | $C_{21}H_{38}O_2$ | 324 | 25.73 | 0.67 |
| methyl 12-hydroxy-13-methoxyoleiate | $C_{20}H_{38}O_4$ | 344 | 26.69 | 0.06 |
| Z,Z-2-methyl-3,13-octadecadienol | $C_{18}H_{34}O$ | 280 | 27.23 | 0.06 |
| methyl Z-13-docosenoate | $C_{23}H_{44}O_2$ | 352 | 27.72 | 0.20 |
| methyl docosanoate | $C_{23}H_{46}O_2$ | 354 | 27.94 | 0.06 |
| methyl tricosanoate | $C_{24}H_{48}O_2$ | 368 | 28.68 | 0.02 |
| squalene isomer | $C_{30}H_{50}$ | 410 | 29.14 | 0.11 |
| dihydrosqualene | $C_{30}H_{52}$ | 412 | 29.57 | 0.05 |
| tetrahydrosqualene | $C_{30}H_{54}$ | 414 | 30.30 | 0.02 |
| methyl hexacosanoate | $C_{27}H_{54}O_2$ | 410 | 31.52 | 0.02 |
| stigmasterol | $C_{29}H_{48}O$ | 412 | 34.56 | 0.01 |
| β-sitosterol | $C_{29}H_{50}O$ | 414 | 35.16 | 0.06 |

Methods of reducing viscosity besides trans-esterification include dilution, micro-emulsion, pyrolysis and catalytic cracking [13], [14], [15], [16].

A high free fatty acids value in the feedstock consumes the catalyst during base catalyzed trans-esterification reaction to produce biodiesel. It also leads to saponification which lowers the yield and increases formation of emulsions in the product making it difficult to separate biodiesel from glycerine [17].

Flash point is specified in biodiesel to serves as a restriction of the amount of alcohol in biodiesel for safety measures in transportation and storage. It is also a biodiesel quality related to the fatty acid structure [18]. In our study, the flash point of the methyl esters (biodiesel) was 302oC. However, flash point can be adjusted through blending biodiesel with petroleum diesel in appropriate proportions [4], [16].

**Table 3:** The Physico-chemical Properties of *Jatropha* biodiesel, compared to the standard specifications of *Jatropha* oil and those of petroleum diesel [7]

| Specification | Standard specification of Jatropha oil | Standard specification of Petroleum Diesel | Methyl esters (biodiesel) | |
|---|---|---|---|---|
| | | | value | method |
| Specific gravity | 0.9186 | 0.82/0.84 | 0.90 | ASTM D-287 |
| Flash point, oC | 240/110°C | 50 °C | 302 | ASTM D-93 |
| Carbon residue, wt.% | 0.64 | 0.15 or less | Nil | ASTM D-189 |
| Cetane Index | 51.0 | 50.0 up | 58.82 | ASTM D-976 |
| Kinematics Viscosity, cSt, 40 oC | 50.73 cs | 2.7 cs up | 2.52 | ASTM D-445 |
| Total sulfur, wt.% | 0.13 % | 1.2 % or less | 0.005 | ASTM D-4294 |
| Cloud point, oC | | | - 6.0 | ASTM D-97 |
| Copper corrosion | | | 1a | ASTM D-130 |
| BS & W, vol.% | | | Nil | ASTM D-96 |
| Ash content, wt.% | | | Nil | ASTM D-482 |

Calorific value, or heat of combustion of plant oils that are commonly used as raw materials for biodiesel production varies from 5443 to14654 kJ/Kg. This is within the range of that of hexadecane, also known as Cetane (10714 kJ/mole), which is used as a reference standard material for the determination of the ignition quality of petroleum diesel [9], [19]. Cetane index is used as a substitute for the cetane number of diesel fuel. The cetane index is calculated based on the fuel's density and distillation range (ASTM D86). Our results (Table 3) indicated that the cetane index of the methyl esters (biodiesel) is 58.82, compared to 51.0 and 50.0 as standard specifications of *Jatropha* oil and petroleum diesel, respectively, which was in agreement with the nil value determined to the parameters "BS & W, vol.%", the volume percentage of base sediment and water, the "carbon residue, wt.%", and the "ash content, wt.%".

## 4 CONCLUSION

The cultivation of *Jatropha curcus* in the poor salty lands north delta in Egypt is feasible. Its seed production is 1390 kg dry seeds/ha/yr. The oil yield is 16.17%. In this study, based on the high free fatty acids%, the acid catalyzed esterification to produce the methyl was preferred. The composition of the produced methyl esters and their physico-chemical properties confirmed the possibility of using it as biodiesel.

**ACKNOWLEDGEMENTS**

This work was supported by Mansoura University from Researches fund. The PI would like to express his thank to Prof. Ahmed Maatook, Agricultural Engeneering Department, for squeezing *Jatropha* seeds, as well as Dr. Fawwaz Agizah, Rasheed Petroleum Company, for some valuable consultations concerning biodiesel characterization.

ISSN 2229-5518

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ISSN 2229-5518

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