Production of Biofuel from Jatropha Plant

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Abstract

In this work, the production of biofuel after cultivation of Jatropha seed in sandy soils taken from sand dunes in Baiji area had been performed. Wastewater of biological wastewater treatment unit in the company is used to irrigate cultivated plants. Jatropha oil is extracted from fruit by compression and the productivity of oil is found to be 1 liter for every three kilograms of the fruit of Jatropha. Jatropha oil is blended with gas oil produced in the North refineries company. Weight percent of jatropha oil in the blend was 10%-20%.

The results showed that the produced biofuel specifications are within the standard limits.

Keywords: Jatropha, Biofuel, Biodiesel

Introduction

Researchers went for quite some time to the production of energy from clean sources and environmentally friendly sources or of few environmental damage instead of using conventional energy sources which has known to cause great environmental damage. Of these methods are the use of watershed to produce electric power, the use of wind power, and the use of solar energy. Each of these methods has their drawbacks and advantages. Thus researchers went to the production of biofuels from plants such as sunflower, palm oil, soybean, and corn [1-4].

Demirbas and Kara (2006) stated that among more than 350 identified oil bearing crops, only sunflower, soybean, cottonseed, rapeseed, and peanut oils are considered as potential alternative fuels for diesel engines. The results were positive but these plants are major sources of human food so research moved towards plants not within human food such as date palm and Jatropha. Ahmed (2016) stated that every year, huge quantities of the produced date palm fruits (more than 30%) are lost in Algeria during various processing stages resulting in a huge loss in the anticipated produced biofuel. Anwar et.al.(2015) mentioned that Malaysia produced 40% of total global demand for crude palm oil. Crude palm oil production in Malaysia has increased more than 8 folds since 1960 to 2013.

Different methods are used to prepare biodiesel. Nicholas et. al.(2006) prepared a biodiesel using a microwave apparatus and stated that this procedure offers a fast, easy way to produce valuable biofuel of oil/methanol ratio at short time. Moreover, the reaction takes place under atmospheric conditions, and can be performed in a batch scales. Qian et. al. (2010) prepared biofuel from Jatropha using solvent extraction. The experimental results showed that solvent volume, methanol/v-hexane ratio, temperature, and time affects considerably the process. They found that properties of fatty acid methyl ester (FAME) product prepared from Jatropha curcas L oil met the ASTM specifications for biodiesel. Ika et. al., (2013) produced biodiesel from jatropha using solvent extraction and in situ transesterification in a single step. They found that methanol to seed ratio and the molarity of catalyst (KOH) affects highly the yield and purity of the produced biofuel. However, they mentioned that stirring speed, temperature, and reaction time have little effects on biodiesel quality. They mentioned that the produced biodiesel quality met the Indonesian Biodiesel Standard. Joshua (2013) chosed jatropha to produce biofuel since it is not a food source to human. Manjunatha et. al. (2015) stated that edible and non-edible oil resources biofuel can be used as asubstitute of diesel. The produced biodiesel is blended with diesel and the blend is used operate CI-Engine. They found that the blend B10 gives the better performance. Peterson et. al (1999) operated a heavy duty diesel engine by a blend of 20% methyl ester of rape seed oil (RME) and 80% 2-D diesel (2-D) for 161000 km. They found that the both pure RME and 20% RME gives lower power than 2-D fuel. More over, smoke density was reduced when using pure RME while it is increased with 20%RME. The results of emission test show that there is a decrease in hydrocarbons, CO, NOx, and particulate matters. However, CO_2 emission is not changed compared to 2-D fuel. After running the vehicle for 163800 km the engine was tested and found better than that which would have been expected with diesel fuel. Engine parts were clean and showed little wear. Nor et. al. (2015) stated that although the use of nonedible oil can replace edible oil, it gives low performance and higher emission. The characteristics of the fuel produced from jatropha can be improved by controlling the operating parameter through the manufacturing process such as catalyst concentration, temperature, reaction time, and molar ratio of methanol to oil. Ibrahim et.al.(2018) stated that there is a huge depletion of conventional fuels and increasing demand of energy. This fact make the researchers to seek on fuel alternatives. Biodiesel had been produced from Jatropha seed oil using sulphated zirconia as catalyst. It is found that the optimum yield depends on oil to methanol ratio, temperature, reaction time, and weight/weight% catalyst load. Dangoggo et. al.(2018) stated that there is an increase in the use of biodiesel due to it is environmental benefits. They used jatropha to produce biodiesel using sulphated zirconia as catalyst. They found that the properties of the produced biodiesel are within the ASTM standard. Hence, it can be used as a replacement or additive to conventional diesel. I. Vinoth Kanna et. al. (2018) mentioned that due to the scarcity of petroleum products, biodiesel is used widely. They stated that biodiesel has a lot of environmental benefits concering the reduced emission of air pollutants. However, it gives higher NOx emission as compared with petroleum diesel.

Yiftach et.al.(2018) stated that Jatropha can be considered as tolerant crop that is cultivated under semi-arid conditions as a biodiesel feedstock. They mentioned that, many projects failed to be commercial. Their results showed that under semi-arid conditions, commercial oil yields of Jatropha can be achieved by balancing vegetative growth with reproductive capacity through the application of optimal irrigation and induced vegetative arrest. Andrew and Hazir (2013) estimated the large scale jatropha plant total site cost, establishment and Initial Infrastructure for the first year to be 0.3 $\$/m^2$ while the Annual operating costs for Years 2 and 3 are 0.088 $\$/m^2$.

Although jatropha needs low quantities of water, using wastewater for irrigation purposes will preserve water sources and eliminate pollution. Abdel-Dayem et.al. (2012) stated that water reuse is regarded by most Arab nations in order to preserve water resources. Arab states currently produce about 11 km^3/year of wastewater. The treated wastewater represents 55% while the reused wastewater is 15%. Waleed and Xiurong (2015) mentioned that Jatropha had been planted in Egypt and wastewater is used to irrigate it. one of the recently planted trees that utilizes wastewater in Egypt. This tree is chosed to be planted in marginal desert land due to its good features. Moreover, it enable to reuse wastewater and make use of this land which itself represents an environment hazard .

Jatropha can be used in Iraq to produce biofuel for its resistance to harsh climatic conditions and the need for little water, short reach, and its ability to grow in the desert or semi desert lands. Traditional gas oil combustion products are soot, hydrocarbon compounds of multiple rings and hydrocarbon compounds that contain nitrogen compounds which also contains carcinogenic compounds. It also contains unburned molecules. The use of biofuel will reduce air pollution. On the other hand it has been shown that biodiesel decomposes in less than a month and this give less pollution than conventional petroleum products that remain in the environment without degradation for many years.

The aims of the present study are: Production of biofuel, Reserve aquatic resources through the use of contaminated industrial wastewater of Baiji oil refineries to irrigate the plants, to reduce environmental load, increasing the green areas, and fixing sandy soil.

Procedure

The work of this study is divided into three stages as follows:

First stage- site preparation and planting

Site preparation is performed by taking sand from the sand dune soil adjacent to the Baiji refineries which has very low pretty sandy soils of significant environmental problem for the region through the sand creep. Jatropha seeds were planted in black polyethylene bags and the germination was around 92%. After ten months of shrubs, small trees were moved to land devoted to agriculture and sandy soils of about 2500 square meter. The distance between any two plants was 3 meter. Agricultural area is located north west of Baiji city (34.990055°N, 43.452722°E). Industrial wastewater taken from North refineries company was used for drip irrigation. Each single plant has consumed not more than 600 ml per day in summer and in winter it was irrigated at a rate of once per month. The use of industrial wastewater prevents throwing it into the Tigris River which suffers from pollution and it also suffers from water scarcity. Moreover, it will conserve water resources and also it contains some of the nutrients which will compensate for the lack of these nutrients. Plant growth was very good and Jatropha fruits were obtained after two years.

Figures (1)-(4) represent photos showing the area of cultivation, different stages of plant growth, and irrigation procedure. The cultivation of plants in such a region would fix sandy soil since the roots of the plant is of complex type reaches a depth more than 1 meter and extends horizontally to a distance of at least 1.5 meters as well as the bushes will work as windbreaks and sand soil creep stopper.

Figure 1 Photo showing area of cultivation

Figure 2 Photo showing plants at certain stage of growth

Figure 3 Photo showing plants at certain Stage of growth

Figure 4 Photo showing irrigation procedure

Second stage – fruit reaping and oil production

In this stage fruit reaping and oil production is performed when the plant arrived to adulthood and produce fruits. Figures 5 and 6 show fruit at different growth stages. It is noted that it is possible to harvest twice a year. Manual reaping is performed since the field is small. The quantity of the product is 400 and 800 kilograms at the first and second year respectively. Then removing the leaves and impurities from fruits manually because the survival of paperwork with fruit will cause oil oxidation and change its characteristics since chlorophyl is an oxidizing substance. The fruit is washed through strong jet of water sprinkled with suits to get rid of dust and other impurities. The oil is extracted through several steps:

Figure 5 photo showing fruits at certain growth stage

Figure 6 Photo showing fruits at certain stage of growth

First step- crushing

The first step is crushing and flipping through a special machine manufactured by the authors. During this step oil is coming out as a result of cells rupture. It is noted that keeping fruit and dough separately from the air during this step prevent oxidation of the oil. It is also noted that slow mixing and flipping process has a positive impact on the formation of large oil droplets which reduces emulsions and help oil to get out easily.

Moreover it is noted that using higher temperature during mixing and crushing will speed oil extraction since its viscosity is reduced, but high temperature is accompanied by chemical and biochemical changes for oil in the dough with the demolition of the sensory cells of the oil.

Step 2 – compression and extraction

The dough contains water, oil, small size Jatropha-nuclei, and crushed tissue. Jatropha oil mixed with water is obtained by compression process and left behind tissues and other impurities. Manual compressor contains a filter that allows only liquids to pass is used.

Step 3 – oil separation from water

In this step oil-water separation is performed by centrifuges spin up to 2000 rpm. Sample of pure oil is shown on Fig.(7). Some of fresh oil characteristics was measured and listed in Table (1). The components of Jatropha seeds are listed on Table (2). It is worth to mention that one liter of fresh oil is obtained from every three kilograms of Jatropha fruits.

Third stage – Preparation of Biodiesel

Three biofuel samples are prepared by mixing pure Jatropha oil with gas oil produced in the North refineries company at weight percent of 10%, 15%, and 20%. Figure (8) shows sample of this mixture. Table (3) shows some of the properties of gas oil produced in the North refineries company while Table (4) includes the standard specifications for gas oil.

Figure 7 Photo showing pure Jatropha oil

Figure 8 Photo showing pure Jatropha oil mixed with gas oil

Table (1) Properties of pure jatropha oil seeds

Property	Value
Flash point , °C	176
Specific gravity	0.9154
Viscosity, cSt	12.5
Pour point, °C	-6

Table (2) Components of jatropha seeds

Component	Weight %
Oil	35
Fats	38
Proteins	17
Moisture	5
Ash	5

Table (3) Characteristics of gas oil produced by north refineries company

Property	Value
Flash point , °C	72
Specific gravity	0.8371
Viscosity, cSt	3.5
Pour point, °C	6
Cetane number, C_{10}	53

Table (4) Standard specifications for gas oil

Property	Value
Flash point , °C	54
Specific gravity at15.6° C	0.85
Viscosity, cSt (maximum)	5.6
Pour point, °C (maximum)	-9
Cetane number, C_{10} (minimum)	53

Results and Discussion

Some properties of the prepared biofuel samples has been tested in the laboratories of North refineries company and the results are listed in Table (5) and presented graphically on Figures (9)-(13). Comparison of pure Jatropha oil properties (Table 1) with that of gas oil produced in the North refineries company (Table 3) indicates that pure Jatropha oil is better than gas oil. Moreover, it does not contain pollutants such as lead, sulfur, and heavy metals which are usually located in petroleum fuels.

Figure (9) shows the effect of blending ratio on flash point. It is obvious that flash point is increased from 72 to 86° C when the blending ratio is increased from 0% to 20%. This is due to the fact that flash point of pure Jatropha oil is 176° C. This feature adds a superiority and security during transport, handling, and use since dealing with fuel of higher flash point is more safe. Moreover, high flash point means lower evaporation losses due to evaporation and also reduces the environmental risk of fumes and health effects on handlers at all stages from manufacture to final consumer.

Table 5 Properties of biofuel blends

Figure (10) shows the effect of blending ratios on C_{10} number. It is evident that C_{10} is increased from 53 to 62 when the mixing ratio is increased from 0% to 20%. C_{10} number is a measure of the energy supplied by the fuel to the machine. This feature adds a superiority for the biofuel since increasing C_{10} means higher energy supplied to engine which enable it to cut more distance.

Figure (11) shows the effect of blending ratios on viscosity. It is clear that increasing blending ratio from 0% to 20% will increase viscosity from 3.5 to 5.1 cSt. This is due to the fact that the viscosity of pure Jatropha oil is 12.6 cSt. Increasing viscosity means increasing the required power for the fuel pump as a result of increased resistance to flow. However, increasing viscosity will provides advantage of maintaining internal parts such as rubber, pumps, piston…etc.. of machines.

Property	blending ratio, (weight %)		
	10	15	20
Flash point , °C	77	82	86
Specific gravity	0.845	0.8447	0.8539
Viscosity, cSt	4.2	4.6	5.1
Pour point,° C	-3	-3	-3
Cetane number, C_{10}	60.4	61.2	62

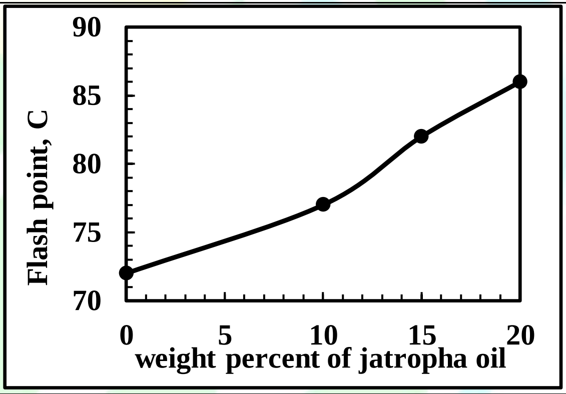

Figure 9 Effect of jatropha oil weight % on flash point

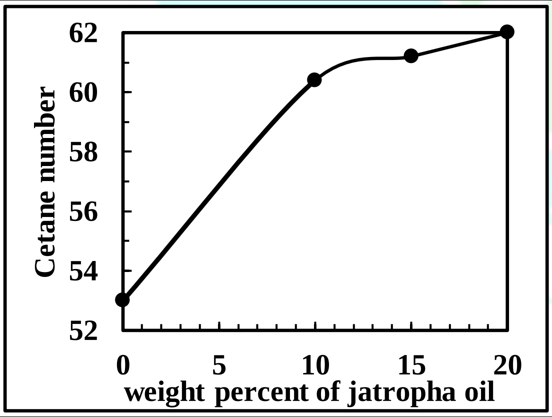

Figure 10 Effect of jatropha oil weight % on cetane number

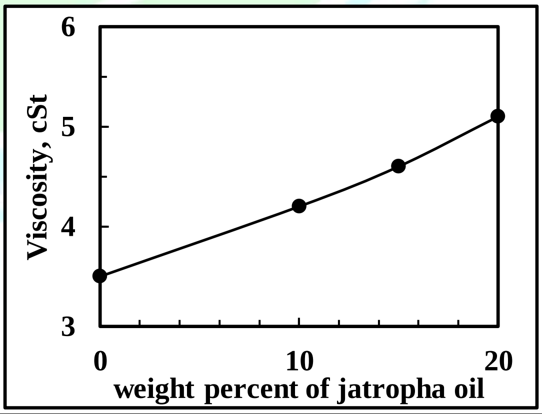

Figure 11 Effect of jatropha oil weight % on viscosity

Figure (12) shows that the specific gravity is increased from 0.8445 to 0.8539 when increasing mixing ratio from 0% to 20%. This is because the specific gravity of pure

Jatropha oil is 0.9154. The increase of specific gravity means increasing the density. This means the ability of tha tank to contain higher weight of fuel. When the fuel is transported by trucks, higher weights of fuel can be shipped through same trucks. Moreover, the vehicle using biofuel will cross longer distance by the same volume of fuel since the energy supplied to the engine is increased.to the engine by the same volume.

Figure (13) shows the effect of blending ratios on pour point and reflected the decrease of pour point from 6 to -3°C when increasing the mixing ratio from 0% to 20%. This is due to the fact that pour point of pure Jatropha oil is - 6°C. The lower pour point means that the use of biofuel would be easier, especially in areas of cold weather and reduce the energy needed to pump fuel in such regions since freezing problems is reduced. It should be noted that the characteristics of the biofuel produced in this study fall within standard specifications for gas oil (Table 4).

The produced biofuel which contains 10%, 15%, and 20% of Jatropha oil is used to operate electric generator of 2 KV for 2 hours. The performance of the generator is not affected at all.

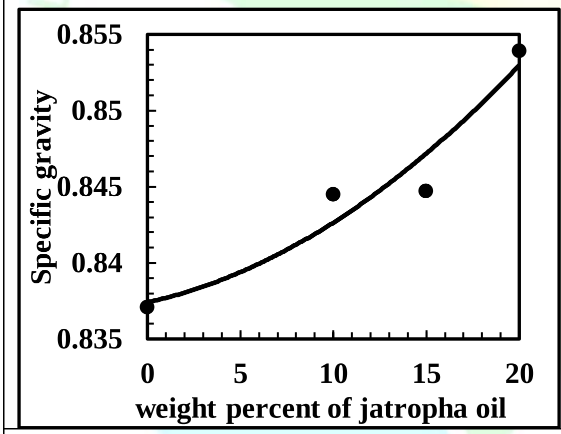

Figure 12 Effect of jatropha oil weight % on spesific gravity

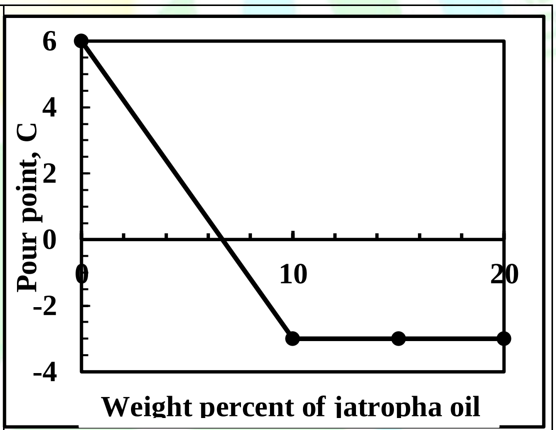

Figure 13 Effect of jatropha oil weight % on pour point

Environmental and Economic Benefits

North oil refineries company, Baiji produces 800 m^3/day of wastewater that contains solids, organic matters, hydrocarbon compounds, toxic compounds, chemicals, heavy metals ,. etc. This wastewater after being treated by a wastewater treatment plants is thrown to Tigris river through a special 5 km long channel constructed for this purpose. This water still have considerable pollutants which have a high impact on the river and its aquatic life. On the other hand, this wastewater will find its way to ground water through a channel causing pollution of the ground water. Moreover, operating the wastewater treatment unit of Baiji oil refineries requires high operating and maintenance cost. It is also expected that the production of the refinery will increase resulting in more wastewater. This requires additional costs and higher pollution impact.

This work allow the use of all wastewater of Baiji oil refineries to irrigate the nearby sandy soil planted with jatropha. The only requirement is pumping station to transfer this wastewater through a pipeline to irrigate the farm. This will prevent Tigris river and ground water from pollution. Moreover, it allow fixing of sandy soil and prevent sand creep and blowing sand.

Table (6) represent data for the proposed project which indicates that extending the results of this work on a large scale project will return all expenses through 2 year.

Table (6) Summary of the proposed project

Item	Value	Notes
Produced wastewater from Baiji oil refinery, m^3/year	292,000	Data from Baji oil refineries
Wastewater consumed for irrigation, $m^3/(1000m^2.year)$	22	Based on the results of the present work, 55 m^3/year is consumed to irrigate 2500 m^2
Planted area, m^2	13,250,000	Based on the available wastewater
Produced jatropha fruit, ton/year	3,975	Based on the results of this work, 2500m^2 produced 800 kg/year
Produced pure jatropha oil, liter/year	1,325,000	1 liter jatropha is produced from 3 kg of fruit
Produced jatropha fuel, liter/year	7,950,000	Each liter of pure jatropha oil can produce 5 liter of fuel (mixing ratio is 20%)
Total Cost of the project (farming and operating the farm of 13250000m^2), USA $	3,350,000	Including all expenses from land preparation till fuel production
Total income, USA $/year	2385000	based on a price of jatropha fuel of 0.3 $/l)

Summary of the Benefits

- Fixing sandy soil and preventing sand creep and blowing sand.
- Dispensing the need for the wastewater treatment station in Baiji and nearby industrial facilities
- Increase the green land
- Employment of more labour and reduce unemployment problems.
- Save water and energy sources.
- Provide a natural environment for many living species.
- Conducting studies and research concerning Jatropha plant and access of roots, stem, and leaf in different areas.
- It is possible to take advantage of the sandy land cultivated by jatropha for planting other plants as a result of the high soil fertility.

It is worth to mention that the nearby fertilizer company and electric power generation company can use their wastewater for the same purposes and get the environmental and economic benefits of such project.

Conclusions

In addition to consuming wastewater of Baiji oil refineries which reduces the cost of treatment unit, other important benefits are gained such as: preserve water sources, eliminate pollution, fixing sandy soil, increasing green area, reduce fuel combustion emmision, reduce sand blowing, and economic benefits.

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