Review and Comparison of Various Properties of Jatropha oil Biodiesel

Konica Sarker
Bangladesh Power Development Board, Dhaka, Bangladesh.
Corresponding author email: konica_eng@yahoo.com

Abstract: 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. This paper deals the various physical-chemical and biological properties of Jatropha oil with environmental impact. Comparison between palm oil, soybean oil and canola oil has also discussed. The major properties highlighted are kinematic viscosity, calorific value, flash point, yield rate, productive life and GHG emission.

Key word: Jatropha Curcas**,** Chemical and physical properties, Yield rate, GHG emission.

1. Introduction

Mobilization of economic development creates a thrusting pressure on petroleum based fossil fuel. But the pollutant emitted from this fossil fuel is harmful for environment and responsible for global warming. Thus to reduce environmental hazard and ensure the energy supply, development of alternative energy sources which are renewable and environmental friendly has drawn the vivid attention in various countries [1]. In this situation, biodiesel can play a prominent alternative to fossil fuel for its biodegradability, non-toxicity, renewability and carbon neutrality [2].But the excess production of biodiesel from agricultural crop has an adverse effect on soil fertility as well as food security. Allowing all these factors much attention should be paid on non-food crops or agricultural waste, especially ligno-cellulosic biomass like switch-grass, willow, or woody oil plants. Among these Jatropha curcas is considered as a potential source of biodiesel. Now-a-days many researchers have done on Jatropha curcas to use it as an ideal feedstock of biodiesel production for its strong adaptability to the environment, especially in terms of drought resistance, high survival rate, and high seed yield [3].

In this study, some important features of Jatropha have highlighted and compared its properties with some major first generation biofuel crop such as palm oil, soybean oil and canola oil. The novel contribution of this paper is to create an attention of investor and policymaker to use Jatropha as a potential source of biofuel by knowing its all properties and comparing with other promising biofuels.

2. Overview and comparison of Jatropha as biodiesel

Biodiesel is a fuel made up by mono-alkyl-esters of long chain fatty acids, derived from vegetable oils or animal fat. The choice and sustainability of the biodiesel source to be used mainly depend on compliance with the required fuel specifications for diesel engine application, availability, price, environmental impact etc. [4]. In this section, various physical-chemical properties, biological properties and environmental aspect of Jatropha oil are discussed. Then compare these properties to palm oil, soybean oil and canola oil.

2.1 Physical- Chemical Properties

Table-1 shows various physical and chemical properties of Jatropha oil [5]. Among these, kinematic viscosity, calorific value and flash point are very important feature of fuel characterization. Now different characteristics for Jatropha oil are discussed below.

Firstly, kinematic viscosity is a significant characteristic of fuel which impacts the quality and efficiency of combustion. The kinematic viscosity of Jatropha oil is much higher than standard diesel fuel. At 20℃ the kinematic viscosity of Jatropha oil is about 47.3 [6], it is about 12 times higher than standard diesel. But to compare with palm oil, canola and soybean oil, it is much lower than these vegetable oils.

Table-1: Physicaland chemical properties of Jatropha oil [5]

Parameter	Jatropha oil
Density at15℃	0.920gr/cm3
Viscosity at30℃	52 cSt
Flash point	240℃
Fire point	274±3℃
Cloud point	971 1C
Pour point	471℃
Cetane number	38
Caloric value	38.20 MJ/kg
Conratson carbonresidue	0.870.1 (%w/w)
Hydrogen	10.52 (% w/w)
Sulfur	0 (% w/w)
Oxygen	11.06 (% w/w)
Nitrogen	0
Carbon	76.11 (% w/w)
Neutralization number	0.92 mg KOH/gr
Saponification value	198.00
Iodine number	94
Monoglycerides	Not detected
Diglicerides	2.7% m/m
Triglycerides	97.3% m/m
Water	0.07% m/m
Phosphorus	290 mg/kg
Calcium	56 mg/kg
Magnecium	103 mg/kg
Iron	2.4 mg/kg

Secondly, calorific value which represents the amount of heat transferred into the chamber during the combustion and indicates the available energy in fuel. The higher calorific value of fuel reduces the specific fuel consumption [7]. Many researchers carried out their research and found that the calorific value of Jatropha oil, which ranges from 38-42.5 MJ/kg. It is little lower than diesel. But it contents high oxygen which helps in complete combustion and increases the combustion efficiency of biodiesel than that of petro-diesel [8-9].

Lastly, flash point is the indicator of igniting and burning property of a fuel. It is important from the point of view of safe handling and storage of the fuel. Due to high viscosity the flash point of Jatropha oil is also higher as compared to diesel. This makes the Jatropha oil relatively less hazardous. Out of palm, canola and soybean oil, only the flash point of canola oil is very much near to Jatropha oil. Properties are summarized in table-2 for easy visualization. These properties of Jatropha oil can be improved by various process such as dilution, micro-emulsion, pyrolysis and transesterification and thus make it comparable to petroleum diesel. Among these trans-esterification is the most usable process for biodiesel production. Flowchart of biodiesel production by trans-esterification is shown in Fig.1.

Table-2: Comparison of physical and chemical properties

Property	Diesel	Jatropha oil	Palm oil	Soybean oil	Canola oil
Kinematic viscosity at 20ºC (cst)	3.92 [6]	47.2 [6]	119.99 [10]	63.82-67.48[11]	78.2[12]
Calorific value (MJ/kg)	44.215[6]	37.83-42.5 [13]	41.3 [14]	39.48[7]	39.78 [9]
Flash point ºC	76[6]	210-240 [13]	>320 [15]	>324 [11]	275-290[12]

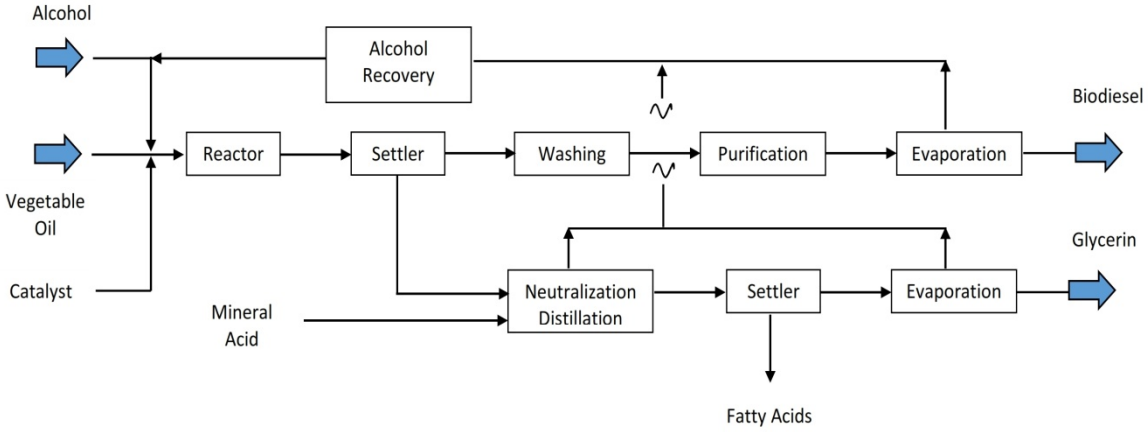

Fig.1 Flowchart of the process of trans-esterification to create biodiesel fuel [9]

2.2 Biological property

Thesource of feed stocks becomes sustainable when it is cost effective. The cost effectiveness of feed stock depends on various factors such as seed yield, area of production, gestation period and raw oil yield during various stages of bio-diesel production-plantation, extraction etc.

In this section, some biological properties (both merits and demerits) of Jatropha plant have discussed. Jatropha is adaptable in both tropical and non-tropical climate with cultivation limits at 30ºN and 35ºS. It also grows in lower altitudes of 0-500 meters above sea level. Now it has spread beyond its center of origin [16]. It has grown on barren, eroded lands, under harsh climatic conditions [17]. But the soil should be well drained as it cannot withstand standing water and having ph 6~8/8.5.It can also be grown and planted in soil with high ph as 8.5~9.5 by using some special techniques [18]. It is suitable with average temperature of 20~28ºC in humid regions but will be died in extreme and prolonged frost conditions [8].

Jatropha curcas is a small tree or large shrub with smooth gray bark, which exudates a whitish colored watery latex, upon cut. It has large green to pale green leaves, alternate to sub-opposite, three to five lobed with a spirally phylotaxis [5].The plant develops a deep taproot which stabilizes the landslides and prevents and controlsoil erosion and reclaim wasteland.It contains 38 to41% oil in seeds and 49 to 62% in kernels [3]. On an average it yields about 2-3.5ton seed per hector per year. Though it has grown in unfertile land, but adequate access of soil nutrition's and water increase the oil yield rate. This production will be increased up to 5 ton dry seed/ha/yr by additional irrigation or an optimal rainfall of 900~1200 mm [8].If we compare some important property of Jatropha oil with palm oil, soybean and canola oil, it is found that out of these only the yield rate of palm oil is higher than Jatropha oil.

The expected lifetime of Jatropha is about 50 years [8] of which over 30 years is fruitful productive life [17].Due to the wide variation in lifecycle duration, the harvestable fruits prediction could not be exact. Vyas and Singh reported that Jatropha plants start yielding from the second year of plantation, but in limited quantity. If it is managed properly, it starts giving 4-5kg per tree from fifth year onwards [19]. Silipet al. [20] showed a wide variation in days to physiologically maturity of fruit, ripening and senescence, which is given in table-3. Due to the heterogeneously maturity of fruits, mechanical harvesting is not be efficient. The ripe fruits of yellow and black colors hould be collected manually in daily basis which increases the labor cost [20].After the oil yielding, Jatropha shell and husk can be used as power generation and the oil cake can be used for biogas production. Spent slurry and ash of biogas is used as manure. Jatropha contains toxic phorbol ester which is responsible for high toxic characteristics of all parts of the plant. For this property pests and diseases do not pose a significant threat to Jatropha. But this toxic phorbol ester is not good for health. It induced cell proliferation,

skin irritation and tumor promotion. So precautions must be taken when handling the oil and other by-products [1]. Many researchers recommended various techniques to reduce this phorbol ester. Among them, Nakao et al. [21] showed a five week soil treatment which is comparatively cost effective. Table-4 shows comparison ofsome biological property of Jatropha, palm, soybean and canola oil.

Table-3 Lifecycle duration or days required by Jatrophacurcas [20]

Reproductive variables	**Days**		
	Min	**Max**	**Average**
Seeding to first appearance of bud	85	98	91.5
Bud development	7	18	12.5
Flowering to fruit set	1	8	4.5
Fruit set to physiological mature fruit or mature green	21	35	28
Mature green to yellow fruit	2	4	3
Mature green to black fruit	3	9	6
Mature green to dry fruit	6	17	11.5
Flower to yellow fruit	24	47	35.5
Flower to black fruit	27	56	41.5
Flower to dry fruit	36	73	54.5

Table-4 Comparison of some biological properties

Properties	**Jatropha oil**	**Palm oil**	**Soybean oil**	**Canola oil**
Yield rate (kg/ ha)	3000 [22]	4000-5000[23]	375~465 [23]	1200-1500 [24]
Economic life	30ys[17]	25-30ys[23]	3-4 months (sowing to harvest) [25]	5 months (sowing toharvest) [26]
Soil condition	in gravelly, sandy and less fertile soil with well drained	well-drained ,deep fertile loamy to loam-clay soil	loose,well-drained soil rich in organic matter	well drained, productive raw crop soil
Nature	non- edible	edible	edible	edible
Application of pesticide	very small	more	small	more

2.3 Environmental impact

Due to the excess use of petroleum diesel the GHG emission increases day by day which is responsible for global climate change. To reduce the GHG, biodiesel is the best choice for its total emission characteristic. The principles GHGs are CO_2, NOx and CH_4. In this section, emissions of GHG from Jatropha in its life cycle are discussed.

Jatropha has a greater carbon stocking ability than other cotton crop which would be helpful for environment. On an average it accumulates 900kg carbon per hector per year. But the yield hypotheses had a significant impact on the GHG emission [27]. Fig. 2 shows the life cycle of Jatropha from its seeding to oil extraction.

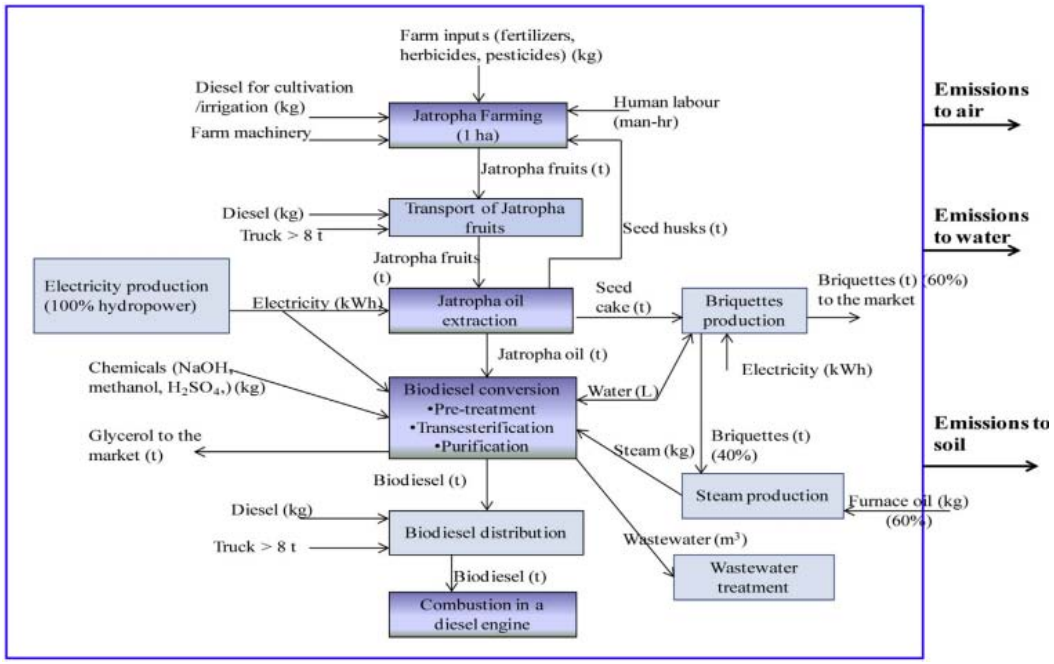

Fig.2: Life cycle of Jatropha from its seeding to oil extraction [1]

CO_2 gas is produced in every step of this life cycle. The amount of CO_2 produces from the every step of is summarized in table-5 and depicted in fig. 3 which is reported by Bilha et al. [1]. Net CO_2 emission from Jatropha is about 848 kg/t. A lot of research carried out to find the emission of CO_2 from Jatropha oil. Zinxin et al. [3] found that, about7.34kg/l and Pandey et al. [8] reported that about 884kg/t CO_2 is emitted from Jatropha. Besides, CO_2, N_2O reduction is another challenge for biodiesel production. Jatropha cannot fix nitrogen to its root, so for better yield of oil, fertilizer is added to Jatropha. As a result the emission of N_2Oincreases and about 9.55 kg N_2O is emitted per hector from Jatropha [1]. This rate is lower than theN_2O emission by palm oil, which emitted 19.09~22.10kg of N_2O-N/h [28]. On the other hand, soybean emitted less N_2O for its nitrogen fixing capability. Though Jatropha contains toxic phorbol ester, the biodiesel is free from it [9].

Table-5 GHG emissions of Jatropha biodiesel in lifecycle [1]

Process	**Biodiesel CO_2 eq. emissions (kg /t)**
GHG emissions from chemical fertilizers application	481
GHG emissions from diesel use for transport of inputs and outputs	31
GHG emissions from diesel use for cultivation	6.1
GHG emissions from diesel use for irrigation	146
GHG emissions from oil extraction and biodiesel conversion	8
GHG emissions from end use of biodiesel	2936
Overall emissions	3608
CO2 absorbed during farming	-2760
Net GHG emissions	**848**

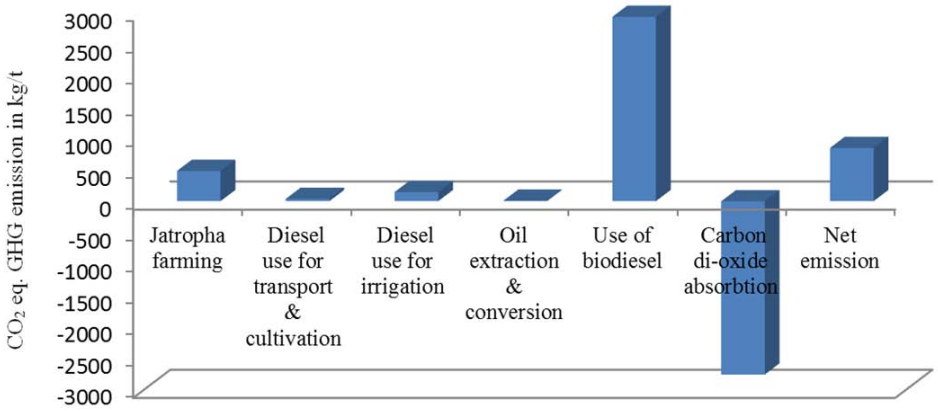

Fig. 3: CO_2 production in every step of life

3. Conclusions

The pros and corns of various properties of Jatropha carcus are addressed in this study. After analyzing the overall features we can recapitulate that the kinematic viscosity of Jatropha oil is higher, but its calorific value is very much near to fossil diesel. It can be grown in degraded agricultural soil with minimal care. Moreover, its average yield rate is about 3 ton. For high yield rate, it requires more supply of water and nutrition. However, it contains toxic phabol ester but the biodiesel is free from it. It has a good carbon sink capability and reduces the CO_2 emission. Like other biodiesel, due to N-fertilizer it emits N_2O to the environment.

References:

[1] Eshton, B.,Katima, J. H. Y and Kituyi, E., "Greenhouse gas emissions and energy balances of jatropha biodiesel as an alternative fuel in Tanzania," Biomass andBioenergy 58 (2013), pp. 95 -103.
[2] Prasad, L.,Pradhan, S.,Das, L.M. and Naik, S.N.,"Experimental assessment of toxic phorbol ester in oil, biodiesel and seed cakeofJatrophacurcas and use of biodiesel in diesel engine," Applied Energy 93 (2012), pp. 245–250.
[3] Wanga, Z., Margaret, M., Calderon, B. and Lu, Y., "Lifecycle assessment of the economic, environmental and energy performance of Jatrophacurcas L. biodiesel in China,"Biomass and Bioenergy 35 (2011), pp. 2893-2902.
[4] Valente, O. S.,Pasa, V. M. D.,Belchior, C.R .P.andSodré, J. R., "Physical–chemical properties of waste cooking oil biodiesel and castor oilbiodiesel blends,"Fuel 90 (2011), pp. 1700–1702.
[5] Khalil, H. P. S. A., Aprilia, N. A. S., Bhat, A. H., Jawaid, M., Paridah, M.T. and Rudi, D., "Jatropha biomass as renewable materials for biocompositesand its applications," Renewable and Sustainable Energy Reviews 22 (2013), pp. 667–685.
[6] Dubey, A. K., Sarviya, R.M. and Rehman, A.,"Characterization of Processed Jatropha Oil for use as Engine Fuel,"Current World Environment Vol. 6(1) (2011), pp. 101-107.
[7] Oliveira L. E., Da Silva M. L. C. P., "Comparative study of calorific value of rapeseed, soybean, jatrophacurcas and crambe biodiesel," International Conference on Renewable Energies and Power Quality (ICREPQ'13), Spain, 20-22 March, 2013.
[8] Pandeya, K. K.,Pragyaa, N. andSahoo, P.K., "Life cycle assessment of small-scale high-input Jatropha biodiesel production in India," Applied Energy 88 (2011), pp. 4831–4839.
[9] Beer, T., Grant,T. and Campbell, P. K., "The greenhouse and air quality emissions of biodiesel blends in Australia," Report for Caltex Pty Ltd. prepared with financial assistance from the Department of the Environment and Water Resources (August 2007).
[10] Available at http://www.chempro.in/palmoilproperties.htm last accessed-20. June.2015
[11] Hammond, E. G., Johnson, L. A. Su, C. Wang,T.and Pamela J. "Soybean Oil" in chapter 13, Industrial Oil and Fat Products, Sixth Edition, Six Volume Set. 2005, CopyrighJohn Wiley & Sons.
[12] Available at http://www.canolacouncil.org/media/515239/canola_oil_physical_chemical_properties_1.pdf
[13] Heikal, E. K. Khalil, S. A. and Abdou, I. K., "Jatropha Bio-Diesel Production Technologies,"International Journal of Bioscience, Biochemistry and Bioinformatics, Vol. 3, No. 3, May 2013
[14] Nagi, J., Ahmed, S. K. and Nagi, F., "Palm Biodiesel an Alternative Green Renewable Energy for theEnergy Demands of the Future,"International conference construction and building technology, 2008.
[15] Available at http://www.beobakels.co.nz/content/docs/material-safety-data-sheets/Palm%20Olein.pdf
[16] Meher,L.C., Churamania, C.P,Arifb, M., Ahmed, Z. and Naik, S.N.,"Jatrophacurcas as arenewablesourceforbio-fuels—A review", RenewableandSustainableEnergyReviews26(2013), pp. 397–407.
[17] Francis, G., Edinger, R. and Becker, K., "A concept for simultaneous wasteland reclamation, fuel production,and socio-economic development in degraded areas in India:Need, potential and perspectives of Jatrophaplantations," Natural Resources Forum 29 (2005), pp. 12–24
[18] Kumar, M. andDwivedi, K.N.,Jatroph: Ekparichay. Kanpur: Chandrashekhar Azad University of Agriculture and Technology Press; 2009.
[19] Vyas, D.K. and Singh, R.N., Technical note,"Feasibility study of Jatropha seed husk as an open core gasifier feedstock," Renewable Energy 2007, 32: 512–7.
[20] Silip, J. J. and Tambunan, A. H., "Lifecycle Duration and Maturity Heterogeneity of Jatrophacurcas L inn," Journal of Sustainable Development Vol. 3, No. 2; June 2010.
[21] Nakao, M., Hasegawa, G., Yasuhara, T. and Ishihara, Y., "Degradation of Jatrophacurcasphorbol esters derived from Jatropha oil cake and their tumor-promoting activity,"Ecotoxicology and Environmental Safety 114 (2015) 357–364
[22] Available at http://www.jatrophabiodiesel.org/economics.php
[23] Shinya, Y. and Yukihiko, M. (eds). Asian Biomass Handbook, 2008, pp. 46-47.
[24] Available at http://www.extension.org/pages/26629/rapeseed-and-canola-for-biodiesel-production#Canola_.E2.80.94_An_Edible_Variety_of_Rapeseed
[25] Available at http://www.harvesttotable.com/2009/05/how_to_grow_soybean/

[26] Aminpanah, H., "Effect of nitrogen rate on seed yield, protein and oil content of two canola (Brassica napusL.) cultivars", DOI: 10.2478/acas-2013-0014
[27] Ndong, R., Vignoles, M., Saint-Girons O., Benoit, G., Pirot, R., Domergue, M. et al. Life cycle assessment of biofuels from Jatrophacurcas in West Africa: a field study. GCB Bioenergy 1(3) (2009), pp.197-210.
[28] Available at http://www.academia.edu/8496875/Nitrous_oxide_emission_from_nitrogen_fertiliser_application_in_oil_palm_plantation_of_different_stages

Profile of Author:

Konica Sarker has completed her M. Sc from Bangladesh University of Engineering & Technology (BUET) and B. Sc from Khulna University of Engineering & Technology (KUET), Bangladesh in Mechanical Engineering. Now, she is working in Planning and Design Department of Bangladesh Power Development Board since 2009, which is utmost responsible organization for power development, generation and distribution all over the country.