A Study of Biodiesel Production from Non-Edible Oil Seeds: A Comparative Study

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Abstract: This study investigated production of biodiesel from non edible oil seeds of *Jatropha curcas* and neem. This is with a view to compare which of the oils when used for biodiesel production is more environmentally friendly and cheaper. The optimum reaction time for transesterification of Jatropha curcas oil to biodiesel was recorded to be 3h while that of neem oil to biodiesel was 2h. This reduces the operating cost of neem biodiesel. Fatty acid methyl esters (FAME) yield of 86.61% with a viscosity of 5.64 cSt was obtained for Jatropha biodiesel using the established operating conditions. This viscosity was used as an index for maximum conversion of biodiesel (BD) for neem oil. The viscosity obtained for neem oil biodiesel was 5.51cSt. An attempt to increase the reaction time does not give any significant difference in the viscosity. Experimental investigations of the different blends of biodiesel from the two oils were tested on an internal combustion engine. The emissions of different blends showed that neem biodiesel has lower emissions of CO and NO_X than Jatropha biodiesel, but CO emissions of Jatropha biodiesel are lower than that of diesel fuel. The NO_X value of petrol diesel is higher than B10 – B50 and B10 – B80 of Jatropha and Neem biodiesel respectively. However, NO_X values of B60 – B100 and B90 – B100 of Jatropha and neem biodiesel are in the range of 5.27 – 10.74% and 1.39 – 11.93% higher than petrol diesel respectively. The physical properties of both biodiesel met the ASTM standard of D-6751.

Keywords: Biodiesel, Biofuel, Emissions, Jatropha curcas oil, Neem oil, Transesterification.

1. INTRODUCTION

The major percentages of energy used in the world today are being generated from fossil fuel sources. These fossil fuels are non-renewable resources that take millions of years to form and their reserves are being depleted faster than they are being regenerated. They are the major contributors and sources of green house gases, air pollution and global warming. Some of the emissions generated from these fossil fuels are CO, CO_2, NO_X, SO_X, unburnt or partially burnt HC and particulate. The production and use of these fossil fuels are raising environmental concerns [1]. This rate of depletion and environmental issue is seriously calling for an alternative. Biodiesel, a form of Biofuel is an answer to this call. It is a fuel derived from renewable biological sources to be used in a diesel engine. Biodiesel fuel is recently attracting increasing attention worldwide as a blending component or a direct replacement for diesel fuel in vehicle engines [2]. Biodiesel blends of up to B20 can be used in nearly all diesel equipment and are compatible with most storage and distribution equipment. These low-level blends generally do not require any engine modifications. Higher blends, even B100, can be used in many engines built with little or no modification [3]. Though biodiesel is gaining popularity, more than 95% of the renewable resources used for its production are edible oils [4] and these have been in conflict with food consumption and also more expensive than petroleum diesel. Due to this fact, it is necessary to look into non-edible oils which are not competitive with consumption and are also cheap. Globally, large amounts of non-edible oil plants are readily available in nature. The ideal vegetable oil for biodiesel must be readily available, its plant should be easy to cultivate and its composition must include a high percentage of mono-unsaturated fatty acids (C16:1, C18:1) [1]. Based on these criteria, *Jatropha curcas* and neem oils have been found to be useful renewable sources for biodiesel production.

Jatropha curcas is drought-resistant oil bearing multipurpose shrub/small tree, belonging to the family of *Euphorbiaceae* [1, 5]. It originates from Central America and is widely grown in Mexico, China, north-east Thailand, India, Nepal, Brazil, Ghana, Mali, Foso, Zimbabwe, Nigeria, Malawi, Zambia and some other countries [5]. The plants grow quickly forming a thick bushy fence in a short period of time of 6–9 months, and growing to heights of 4 m with thick branches in 2–3 years [6]. It grows in arid and semi arid climates and in a wide range of rainfall regimes, from 200 to 1500 mm per annum [5]. It can survive in poor stony soils [7], and has a life span of 50 years [8]. *Jatropha curcas* can produce significant amounts of oil in their respective seeds [1]. The oil content of the seeds varies from 30 to 60% depending on the variety, place and the method of oil extraction [9].

Neem (*Azadirochta indica A. Juss*) is a native Indian tree well known for its medicinal features. Most of the parts such as leaves, bark, flower, fruit, seed and root have applications in the field of medicine [10]. It is an evergreen tree related to mahogany, growing in almost every state of India, South-

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East Asian countries and West Africa [11]. It grows in drier areas and in all kinds of soil. It contains several thousands of chemicals which are terpenoids in nature. A mature neem tree produces 30 to 50 kg fruit every year and has a productive life span of 150 to 200 years [11b]. It has the ability to survive on drought and poor soils at a very hot temperature of 44°C and a low temperature of up to 4°C [12], and its high oil content of 39.7 to 60% [13].

To date, reports on the use of these non edible oils, in particular neem oil from Nigeria, for the production of BD are not available while that of *Jatropha curcas* oil are limited [14]. The fatty acid compositions of the oils (Table **1**) and their physico-chemical properties (Table **2**) have been investigated previously [15]. This article presents the results of a study conducted on BD production from Nigerian non edible oils using alkali-catalyzed transesterification method, and tested in an internal combustion engine. This is with a view to compare which of the oils when used for biodiesel production is more environmentally friendly. The results of this study would form a basis for the development of a database for biodiesel production from these feedstocks, especially in countries where they are in abundance.

2. MATERIALS AND METHODS

2.1. Materials

The *Jatropha curcas* oil was obtained from Ikere-Ekiti while neem oil was bought from National Research Institute of Chemical Technology, Zaria in Nigeria. The conventional diesel fuel was purchased from Obafemi Awolowo University's filling station, Nigeria. Analytical grade chemicals including, methanol, sodium methoxide, anhydrous calcium chloride, sulphuric acid, sodium thiosulphate e.t.c. were obtained from Sigma Aldrich, Germany.

2.2. Two-step Acid-base Catalyzed Transesterification

These crude non edible oils when transesterified using NaOH catalyst produced a significant amount of soaps from saponification side reaction. Therefore, a two step process

Table 1. **Fatty Acid Compositions of *Jatropha Curcas* Oil and Neem Oil**

Fatty Acid	Jatropha Curcas oil [22]	Neem oil [13]
Myristic 14:0	0.1	-
Palmitic 16:0	14.2	18.1
Palmitoliec 16:1	0.7	-
Margaric 17:0	0.1	-
Stearic 18:0	7	18.1
Oleic 18:1	44.7	44.5
Linoleic 18:2	32.8	18.3
Linolenic 18:3	0.2	0.2
Arachidic 20:0	0.2	0.8
Saturated	21.6	37
Monounsaturated	45.4	44.5
Polyunsaturated	33	18.5

Table 2. **The Physicochemical Properties of Neem oil and J*atropha Curcas* Oil**

Properties	Neem Oil [15a]	Jatropha Oil [15b]
Acid Value (mgKOH/g)	32.538	35.8
Iodine Value	81.28	-
Viscosity (cSt)	@30^{o}C 43.75	@room temp 41.4
Saponification	199.86	193
Physical state at room temperature	Liquid(Golden yellow)	Liquid(Golden yellow)
Cloud point (^{o}C)	13	10
Pour point (^{o}C)	7.0	2
Density at room temperature (Kg/m^3)	918.2	895

acid catalyzed esterification followed by alkali catalyzed transesterification was employed according to the method of Berchmans and Hirata [16].

2.2.1. Acid Pretreatment (Acid Catalyzed Esterification)

The crude oil was heated at 60^{o}C for about 10 mins and mixed with methanol (60%w/w of oil). To the mixture was added 1 – 1.2% w/w of concentrated H_2SO_4. The resulting mixture was then stirred on a magnetic hot plate for 1h at 50^{o}C, after which it was allowed to settle for 2h. The pre-treated oil was separated from the methanol-water phase at the top.

2.2.2. Base Catalyzed Transesterification

Optimum reaction temperature and amount of catalyst concentration had been investigated and reported by [17] to be 333 K and 1 wt% NaOH as reaction temperature and catalyst loading, respectively. The oil to alcohol ratio of 1:6 was also reported by [15b] to give the best result when compared with oil to alcohol ratios of 1:3 and 1:4. Batch reactions were carried out in a 250 mL Erlenmeyer flask containing 100g of oil. These were done on a shaker at a temperature of 333 K keeping the rate of agitation constant at 200 rpm for oil to alcohol ratio of 1:6. The alcohol used was methanol. A catalyst of 1% wt of sodium hydroxide was dissolved into an amount of alcohol according to the oil to alcohol ratio. The alcohol base mixture was added to the oil, and the reaction was allowed to run for various periods of 15 min, 30 min, 1 h, 2 h, 3 h and 3.5h.

The sample collected was allowed to settle for twelve hours in a separating funnel by gravity settling into a clear, golden liquid biodiesel on the top with the light brown glycerol at the bottom. After this period, the glycerol was drained off from the bottom of the separating funnel. The raw biodiesel was water washed three times so as to remove the non - reacted catalyst and glycerol off. To get a pure biodiesel free of methanol, this was purified in a rotary evaporator in order to remove the excess methanol. Following this, the ester phase was dried over anhydrous calcium chloride. The biodiesel produced were analyzed for the following parameters: methyl esters, pour points, flash points, cloud points, density, moisture content and kinematic viscosity at 313 K.

2.3. Analysis

2.3.1. HPLC Method

The HPLC analysis was conducted according to the method shown by Dubé *et al*. [18] and Darnoko and Cheryan [19].

2.3.2. Characterization of BD

The characterization of the biodiesel was carried out according to the methods used by Aransiola *et al*. [17]. The parameters are determined with the standard methods used which are presented in Table **3**.

2.4. Investigation of Biodiesel on Internal Combustion Engine

The investigations on the combustion characteristics of the conventional diesel, neem methyl ester (B100) and its blends were conducted on a single cylinder one-stroke 165F jet diesel engine having a rated output of 3.23kw at 2600 rpm. This was fueled with prepared test fuels. The emissions (CO and NO_x) were measured through an automatic EGA4 palm top flue gas analyzer having Ni-MH

3. RESULTS AND DISCUSSION

The production of biodiesel from Jatropha oil is depicted in Fig. (**1**). As can be observed from this figure, the FAME yields of 86.61% and 86.63% were obtained at reaction times of 3 and 3.5h respectively, with viscosity values found to be 5.64 cSt and 5.65 cSt respectively. Optimally, the reaction time of 3h was chosen since there is no significant difference in both the FAME yield and the viscosity values of these reaction times. Similar observation has been reported by Bajpai and Tyagi [20]. In their study, Bajpai and Tyagi obtained maximum yield of FAME between 333 K and 353 K when oil to alcohol molar ratio was 1:6. The optimum viscosity result of the *Jatropha curcas* oil BD was used as a yardstick for BD from neem oil to determine when the conversion was complete. The viscosity values obtained for neem oil biodiesel at reaction times 2, 2.5 and 3h were approximately 5.51cSt (see Fig. **2**). This implies that the conversion was complete at reaction time of 2h. The fuel properties of both Jatropha and neem biodiesel agree with the standards of the American Standard Testing Method. This is shown in Table **3**.

The results for the various emission data generated are presented in Figs. (**3** and **4**). The emissions of different blends showed that neem biodiesel has lower emissions of CO and NO_X than Jatropha biodiesel, but CO emissions of Jatropha biodiesel are lower than that of diesel fuel. The emissions of CO of both Jatropha and Neem biodiesel decreased as the biodiesel blends tend towards B100, and they both gave less carbon monoxide (CO) when compared to petrol diesel. The emissions of NO_x increased with the biodiesel blends. The NO_X value of petrol diesel is higher than B10 – B50 and B10 – B80 of Jatropha and Neem biodiesel

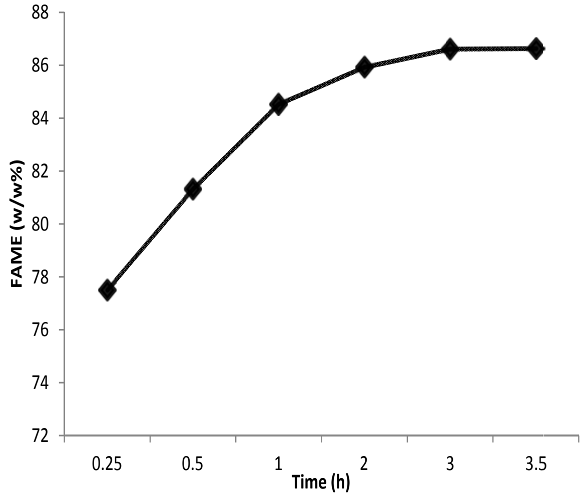

Fig. (1). Plot of fatty acid methyl ester concentration against Reaction Time at Reaction Temperature of 333K for oil to alcohol molar ratio 1:6.

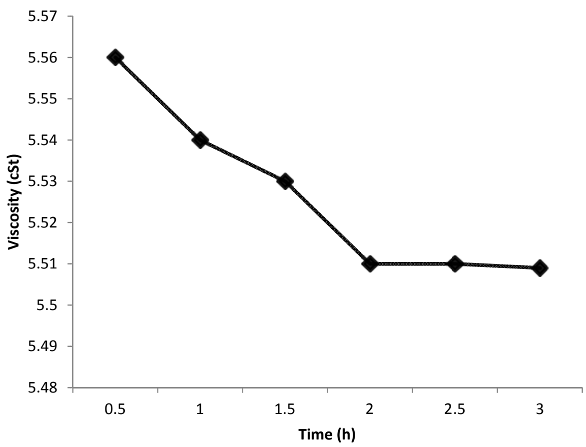

Fig. (2). Plot of Viscosity of Neem biodiesel against Reaction Time.

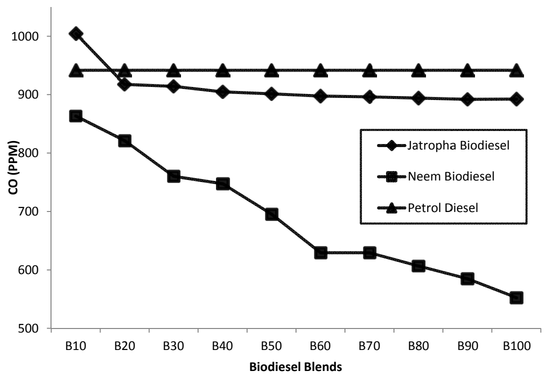

Fig. (3). The plot of CO Emissions against different Blends of Jatropha Biodiesel, Neem Biodiesel and Petrol Diesel.

respectively. However, NO_X values of B60 – B100 and B90 – B100 of Jatropha and neem biodiesel are in the range of 5.27 – 10.74% and 1.39 – 11.93% higher than petrol diesel respectively. The percentage increment between B100 and diesel was 10.74%. Previous investigation has shown similar trends for CO, NO and NOx emissions while running the diesel engines with karanja, neem, Honge, Jatropha and sesame oil methyl esters [21].

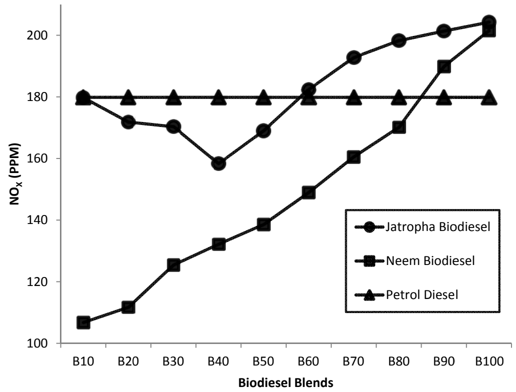

Fig. (4). The plot of NO_X Emissions against different Blends of Jatropha Biodiesel, Neem Biodiesel and Petrol Diesel.

Comparing the use of these two oils; *Jatropha curcas* oil and neem oil for biodiesel production with reference to emissions generated, biodiesel from neem oil was found more environmentally friendly and better. Considering the reaction time for complete conversion, neem biodiesel was found to have a reduced reaction time of 2h compared to the 3h completion time of Jatropha biodiesel; this reduced reaction time of neem biodiesel will lead to its reduced operating and production costs

4. CONCLUSIONS

In this article, a comparative study on the production of biodiesel from non edible oil seeds of *Jatropha curcas* and neem was carried out. The neem biodiesel and its blends were found to have lower emissions of CO and NO_X than Jatropha biodiesel. This makes neem biodiesel to be more environmentally friendly than Jatropha biodiesel, though both of them were found to meet the American Standard Testing Method. The reaction time for complete conversion of neem oil to biodiesel is lower than that of Jatropha curcas oil to biodiesel; inferring lower production cost in neem biodiesel than in Jatropha biodiesel.

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Table 3. Results of Characterization of *Jatropha Curcas* Oil Biodiesel and Neem Oil Biodiesel

Properties	Jatropha curcas oil Biodiesel	Neem oil Biodiesel	Biodiesel Standard	Test Method
Flash point (°C)	170	149	130 (min)	ASTMD – 93
Moisture content	Nil	Nil	0.050 max	ASTMD – 2709
Kinematic viscosity	5.64	5.51	1.9 – 6.0	ASTMD – 445
Cloud Point (°C)	3	5	-	ASTMD – 2500
Specific gravity at 15/15°C	0.880	0.876	0.860 – 0.900	-
Pour point (°C)	-6	3	-	ASTMD – 97
Cetane Number	-	46	45 - 55	ASTM-D 975

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CONFLICT OF INTEREST

None declared.

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