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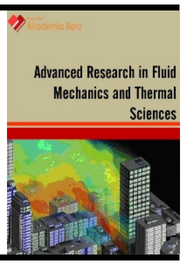

Green energy initiative: An overview of biodiesel production from jatropha feedstock in Nigeria

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ABSTRACT

Increase in global development of renewable energy sources as sustainable alternatives to the conventional fossil fuels witnessed in recent time is linked to greenhouse gas (GHG) emissions; high dependency on imported fossil oil especially in the developed world; non-renewable nature of fossil fuels; price volatility of petroleum products and instability in the oil producing areas. Therefore, bioenergy appears to offer hope for addressing these concerns while also providing new opportunities for farmers in developing and developed countries alike. Among the many possible resources, biodiesel has received the most attention as a promising substitute for conventional petrol-diesel fuel. The production of biodiesel (methyl esters) from Jatropha plant is currently generating interest in every economy of the world as an alternative means of producing liquid fuels from biomass and have gather relevance due to the environmental advantage the process offers. Biodiesel is a renewable source of energy that can facilitate clean air, readily usable in existing engines and transport facilities, capable of generating employment and income for citizens but has not been fully tapped. Hence, efforts are being made to explore this economically competitive, environmentally acceptable and readily available alternative source of energy. Therefore, the paper provides a review of Jatropha as a feedstock for biodiesel production in Nigeria. Focusing on biodiesel development from Jatropha feedstock, the objectives of reviewing its current trends in the production of this biofuel will hold an immense benefit. The biodiesel fuel properties and potential of Jatropha towards environmental sustainability, poverty alleviation, and more importantly improve economic development for rural communities were highlighted.

1. Introduction

Present environmental concerns with climate change has rekindle interest in production of biodiesel from Jatropha oil in many countries. Numerous researches have demonstrated that, the oil obtained from the seed of Jatropha curcas is most suitable for biodiesel production. This is due to its ability to grow within a short period of time, easy to cultivate, less requirement cultivating land and

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high oil content [1]. Therefore in order to make this system sustainable, large-scale plantation schemes of Jatropha should be encourage at every generation as this will critically reduce the rate of unemployment and improve the income earning of poor [2]. Thus, biodiesel production form Jatropha oil will automatically reduce the importation of petroleum based fuel and that can increase the economic growth of the nation [3]. Moreover, using biofuel in our car and various engine will lessen the emission of carbon dioxide, sulfur, and hydrocarbon during combustion process [4]. Furthermore, all the above mention properties of biodiesel was because they are manufactured by plant during photosynthesis [5]. Globally, there have been major strides in production and the use of biofuels, especially in Brazil, China, India and the United States [6]. Yet there has been relatively little action in Africa, except for South Africa. In Africa, countries growing sugar cane, mainly for sugar production, could with minimum effort either expand their activities in bioethanol production or initiate bioethanol production projects. These include Angola, Congo, Democratic Republic of Congo, Côte d'Ivoire, Ghana, Kenya, Malawi, Mauritius, Mozambique, Nigeria, South Africa, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe. Of these, Kenya, Malawi, Mauritius, South Africa and Zimbabwe have all at one time or other used bioethanol as a transport or domestic fuel [7].

Africa's biofuel activities are concentrated in South Africa. South African company, has installed a test processor and has shown that a blend of five per cent biodiesel and 95 per cent petroleum diesel improves engine performance, offers enhanced lubricity and some reduction in emissions [8]. Although, Nigeria is endowed with sufficient renewable energy resources to meet its present and future development requirements, still depends on foreign nations for the supply of fuels. So it becomes urgent for Nigeria to search for other potential means of improving her already pulverized economy [9].

While agriculture has been the mainstay of the nation, contributing more than any other sector to our GDP since independence, crude oil has been, on the other hand Nigeria's major foreign exchange earner especially in the past 3 to 4 decades [10]. However, over dependent on revenue generated from the oil and gas sector alone to service many other areas of the Nigerian economy is a matter of great concern, especially in this era of global crunch where the price of crude oil dwindles every day and climate change is also on the rise [11]. Therefore, urgent strategies are required to arrest the situation and it is not late to diversify into green economy. It is therefore time for us as a nation to start looking into the alternatives available especially in the production of alternative fuel for energy generation and transport sector. Among the alternative energy considered to replace the dwindling conventional transportation fuel in Nigeria, biodiesel and bio-ethanol, are on the vanguard [12, 13]. Furthermore, it is worthy to note that rural bioenergy is still the predominant form of energy used by people in less developed countries such as Nigeria. Thus, most rural areas, particularly in remote locations, the distribution of energy generated from fossil fuels can be difficult and expensive [14]. Therefore exploring biofuel based renewable energy can facilitate economic and social development in communities if projects of sustainable development are intelligently designed and carefully executed with local inputs and cooperation [15]. The fact that Jatropha may grow and produce on marginal soil and not suitable for food crops makes it ideal for use as energy and fuel source [16]. Moreover this fuel is monoalkyl esters of fatty acids derived from vegetable oils and animal fats that is usually produced by transesterification of vegetable oils or animal fats with methanol or ethanol [17]. Furthermore, with the available uncultivated arable land, relatively cheap unemployed labour and appropriate climatic and soil conditions, a substantial increase in biofuel production can be achieved without compromising food security [18]. Hence, it is necessary to explore non-edible oilseeds, such as Jatropha for sustainable biodiesel production. In view of this therefore, the paper will exploits the challenges associated with biodiesel production from Jatropha feedstock with objectives of reviewing the current situation and probable future trends in Nigeria.

2. Biodiesel development historical perspectives

Biodiesel was among the first alternative fuels to become known to the public. It colour ranges from light brown to dark yellow liquid. It is biodegradable, non-toxic with significantly fewer emissions than petroleum-based diesel. Some of the distinguishing characteristics includes; practically immiscible with water, high boiling point and low vapour pressure [19]. The advantage of this fuel is that it can be used in existing vehicles as blended with little or no engines modification [19]. Biodiesel can be produce from a wide range of feedstock, including fresh soybean oil, mustard seed oil, waste vegetable oil, palm oil, rapeseed, sunflower, soybean, Jatropha, copra, palm, groundnut and cotton seed [13]. The historical developments of the biofuel particular biodiesel is the driving factors for its advances which are more of economics and politics than technological [20]. In 1853, transesterification was carried out on vegetable oil in the search for a cheap method to produce glycerin for producing explosives during World War II by Duffy and Patrick [21, 22]. These follows by the establishing of Biodiesel as a concept by Belgian scientist Chavanne in 1937 who patented the Procedure for the transformation of vegetable oils for their uses as fuels [23]. However, it was not until 1977 that first patent on commercial biodiesel production process was applied for by Expedito Parente; a Brazilian scientist [24]. A patent for an efficient thermal engine which was to be operated on peanut oil was filed in 1892 by Rudolph Diesel in Germany. By 1893, Diesel's invention was demonstrated in an exhibition in Paris. Within five years of its invention, Diesel's engine ran on its own power with 75% efficiency against its initial 26% efficiency [25]. The EU is by far the largest producer of biodiesel, responsible for 95 percent of world output. In humid tropics, oil palm is the most important biodiesel feedstock, with Indonesia leading in production followed by Malaysia [26]. The main biodiesel feedstocks are soybean and rapeseed, with the main producers in the Americas and the EU respectively as shown in Table 1.

Table 1
Feedstock for Biodiesel Production in different Countries

Country	Feedstock for Biodiesel
USA	Soya Bean
Brazil	Soya Bean
Europe	Rape seed oil(>80) and Sunflower oil
Spain	Linseed and Olive oil
France	Sunflower oil
Italy	Sunflower oil
Ireland	Animal fat. Beef tallow
Indonesia	Palm oil
Malaysia	Palm oil
Australia	Animal fat, Beef tallow and rapeseed
China	Guang pi
Germany	Rapeseed oil
India	Jatropha
Ghana	Palm oil, Palm nut,Coconut oil

Source [27, 28]

Although, the biofuel industry is facing a major challenge of feedstock availability, several processing options are available for the biodiesel production. Hence, the choice of a particular technology is dependent on catalyst, the source, type and quality of feedstock. Therefore, it is essential to utilize cheap feedstock to reduce the overall production costs.

3. Jatropha potential as feedstocks for biodiesel production

Numerous feedstocks have been experimented in biodiesel production. Advancement from such experimentations led to establishment of waste-to-wealth biodiesel production. Some of the biomass feedstock that has been intensively studied as raw materials for biodiesel production includes desert date (Balanites aegyptiaca), castanhola (Terminalia catappa), rubber tree (Hevea brasiliensis), tung (Vernicia fordii), milkweed (Asclepias syriaca), Zanthoxylum bungeanum, radish (Raphanus sativus), Ethiopian or Abyssinian mustard (Brassica carinata), sesame (Sesamum indicum), Jojoba (Simmondsia chinensis) [13, 29]. Another notable success is the use of Jatropha or the “miracle plant “in many developing countries. Jatropha shown in Figure 1, is a second-generation dedicated energy crop that has the ability to survive in marginal lands. Its seeds contain non-edible oil with properties that are well suited for the production of biodiesel. The fact that it can be cultivated in almost sahelian region of the country with minimal irrigation and less intensive care as indicated in Figure 2, made it suitable for peasant farmers [30]. Furthermore, Jatropha feedstock could eventually evolve into a high yielding oil crop and may well be productive on degraded and saline soils in low rainfall areas. Its by-products may possibly be valuable as fertilizer, livestock feed, or as a biogas feedstock. In addition, its oil can have other markets such as for soap, pesticides and medicines, and can help reverse land degradation [31]. Jatropha had economic importance, in Cape Verde about 35,000 tons of Jatropha seeds was exported per year to Lisbon and Marseille where it’s oil are used for soap production [32, 33]. Furthermore, Jatropha’s potential as a petroleum fuel substitute has long been recognized and used during the Second World War as a diesel substitute while its glycerin by-product was valuable for the manufacture of nitro-glycerine [34].

Fig. 1. Jatropha tree with seeds

Thus, in terms of its viability as a cash crop, experience with Jatropha production in sub-Saharan Africa has found that yields are marginal at best. Hence, holistic schemes that embrace Jatropha production, oil extraction and utilization in rural communities appear the most viable, particularly where its other benefits are recognized, such as reversing land degradation [35, 36]. Jatropha biodiesel has good fuel properties, comparable to or even better than petroleum diesel [19]. As reported by Farouk, Mohd jafar [3], it’s higher flash point than diesel, makes it a safer fuel. Other advantages are the almost zero Sulphur content and the reduced amount of carbon monoxide, unburned hydrocarbons and particulate matter in the exhaust [37]. However, biodiesel high viscosity at low temperature, leading to flow problems are some few technical issues that need to be resolved [38].

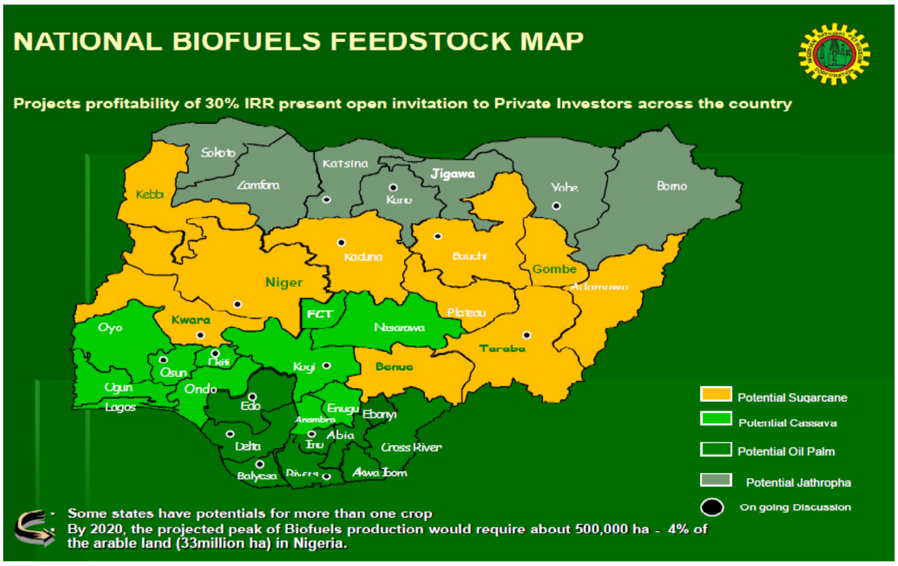

Fig. 2. Map showing grown regions of different biofuels feedstock [39]

In Nigeria, Jatropha is yet to be appreciated as a viable economic crop. Its cultivation is still limited to its use as decorative plant or as hedge crops in rural communities. However, various development projects are ongoing across the country for its use as feedstock for biofuel production [50]. Studies on the use of *Jatropha curcas* plant revealed that it has oil yield of 49.1% compared to oil yield of 39.7% from neem [40]. Therefore, it can be clearly understood form an investigation carry out by Halilu, Misari [41], on the agro-morphological traits, oil content, and local usage of Jatropha (J. curcas) crop in the Northwest part of Nigeria as provided in Table 2, that there is a bright future for enhanced productivity of Jatropha as a renewable energy crop in Nigeria because of the high oil contents and variability of the Jatropha. Hence it has become imperative for Nigerian government to actually embrace Jatropha cultivation for efficient and proper utilization in biodiesel production for sustainable energy production, create more jobs and in turn reduce rural-urban migration [42].

In addition, edible vegetable oils such as palm oil, soybean oil, sunflower oil, coconut oil, rapeseed oil and tung oil have been investigated. However, the most reported non edible feedstock are *Jatropha curcas* and Neem (*Azadirachta indica*). Studies have suggested that *Jatropha curcas* oil could be a useful feedstock for biodiesel production, with a dramatic reduction in cost of production. Moreover, the use of *Jatropha curcas* oil could promote global acceptance and commercialization of biodiesel as an alternative source of energy [19, 25].

Furthermore, with high lipid contents and fast growth rate, Jatropha have the potential to mitigate the competitions for land-use and food-for-fuel conflicts as shown in Table 3.
Although, Biodiesel technology is still in the emerging phase in Africa .However, in spite of feed stock availability, current biodiesel production exists only at research scale. Trial production of biodiesel from palm kernel oil, and other edible and non-edible feedstocks is also being researched in some Nigerian universities [30, 43].

4. Biochemical conversion of Jatropha oil to biodiesel

Jatropha oil is a type of non-edible vegetable oil. Its biodiesel is considered as a potential alternative to fossil diesel fuel [45]. This is due to the fact that its methyl ester properties are similar to diesel fuel and also because the plant has the ability of absorb CO2 from the atmosphere [46]. Therefore utilization of this oil as a new source of fuel for diesel engine has tremendous scope in alleviating the pressure on energy resources [4]. Jatropha oil can be obtained from seeds by mechanical or solvent extraction. The extracted oil is then filtered and excess solvent is removed by using a rotary evaporator at 40°C. Although, oil yield depends on the method of extraction; the percentage yield is usually ranges from 28–32% using presses and up to 52% by solvent extraction [19]. Finally, the crude oil is stored in a freezer at −2°C for subsequent analysis [47].

Table 2
Jatropha carcus L. oil content in Northwest Nigeria communities [41]

State	Local government area	Provenance	Oil content %	100-seed weight (g)
	Birnin kudu	Kangire	42.57	41.582
Jigawa	Birnin kudu	Burum	36.70	69.743
	Birnin kudu	Masaya	31.52	59.043
	Giwa	Iyatawa	56.36	54.394
	Giwa	Bakin gada Gangara	54.05	48.391
	Giwa	Farin gida	40.32	59.698
Kaduna	Giwa	Danjawei Sabon-gida	38.50	80.046
	Birnin-gwari	Dogondawa	51.46	52.975
	Lere	Kayarda	47.13	66.199
	Zaria	Kakeyi	42.99	54.452
	Soba	Soba	33.13	41.116
	Gwarzo	Gwarzo	45.81	47.08
	Gwarzo	Muradi/Tashan gajere	36.31	49.757
Kano	Takai	Dirpindai	45.51	51.185
	Makoda	Welare	41.87	36.98
	Rano	Ruwan kanya	39.17	42.83
	Dutsenwai	Karohi 1	51.85	45.012
	Faskari	Dukamawa	51.12	59.229
Katsina	Charanchi	Kuki	49.65	36.915
	Malumfashi	Dan janku almakiyayi	38.55	51.282
	Bakori	Kakumi 1	38.36	56.228
	Funtua	Bogire (Rufan kifi)	23.26	54.349
	Wasagu	Maga Danko	59.74	59.299
	Argungu	Unguwar Maifada	36.87	50.962
Kebbi	Alero	Gangije	33.86	41.223
	Alero	Jega Birni	28.56	60.228
	Zuru	Sabongari Dabai	21.78	35.233
	Tureta	Bella Town	51.27	44.716
	Shagari	Kajiji	49.32	28.558
Sokoto	Tambuwal	Barkeji	35.33	50.332
	Bodinga	Pompo bodinga	23.81	44.615
	Kware	Tsaki	23.24	40.081
	Talata Mafara	Takai Tsafe	61.83	46.903
	Bungudu	Dandotondaji	55.50	60.941
	Gumi	Daki takwas	30.15	55.967
Zamfara	Tsafe	Chida	28.05	46.6
	Tsafe	Magazu	27.31	37.186
	Gusau	Nasarawa Wanke	21.33	37.186
	Bukkuyum	Zugu	20.29	30.879
Mean			**39.14**	**49.445**
CV (%)			**29.11%**	**21.99%**

Table 3
Estimated oil content, yields and land requirement of some selected biodiesel feedstock. [44]

Feedstock	Feedstock Status	Oil yield (L/ha/ year)	Oil Content (%wt in Biomass)	Required Land (M ha^{-1})	Biodiesel productivity (Kg/biodiesel/ha/year)
Oil palm (*Elaeis guineensis*)	Edible	5,950	30 to 60	45	4747
Jatropha (*Jatropha curcas L.*)	Non-edible	1892	Kernel: 50 to 60 Seed: 35 to 40	140	656
Canoda /Rapeseed (*Brassica napus L*)	Edible	1190	38 to 46	223	862
Soya bean (*Glycinemax L)*	Edible	446	15 to 20	594	562
Corn / Maize(Germ) (*Zeamaysl*)	Edible	172	44 to 48	1540	152

5. Transesterification process

The transesterification process has been proven worldwide as an effective mean of biodiesel production and viscosity reduction of vegetable oils [48]. The process involves reacting triglyceride with alcohol in the presence of a catalyst to produce glycerol and fatty acid esters. Reports have indicated that Jatropha oil can be used as a source of triglycerides for the production of biodiesel by esterification and/or transesterification [17, 19]. The process involves mixing oils with sodium hydroxide and methanol or ethanol. During the esterification process, the triglyceride in vegetable oil or animal fat reacts with an alkoxide functional group in alcohol normally methanol in the presence of catalyst that has already been mixed the alcohol to form alkyl ester (biodiesel). If a base such as NaOH is used for transesterification the reaction is said to be via nucleophile (Figure 3) where as if an acid is utilized in the reaction, it is said to be electrophile (Figure 4). However, the chemical processes in Figure 3 can represent the process for biodiesel production from Jatropha [43, 49]. If methanol is used in the chemical reaction, methyl esters are formed, but if ethanol is used, then ethyl esters and glycerin are formed. Furthermore, some minor constrain are experience with biodiesel production in biofuel industry is high free fatty acid (FFA) in some oil such as Jatropha oil. For alkali-catalyzed transesterification reaction, FFA prevents the completion of the reaction. As such, anhydrous triglycerides and alcohol are necessary to minimize the production of soap [16].

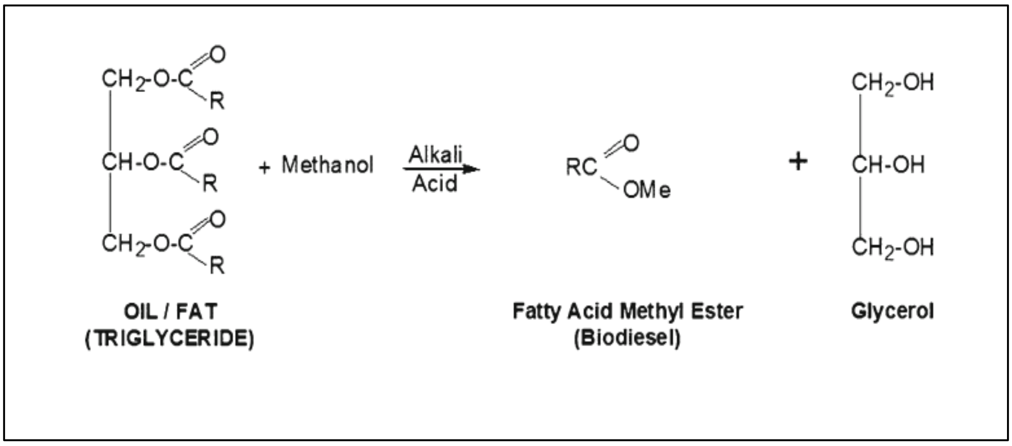

Fig. 4. Transesterification of Jatropha oil [50].

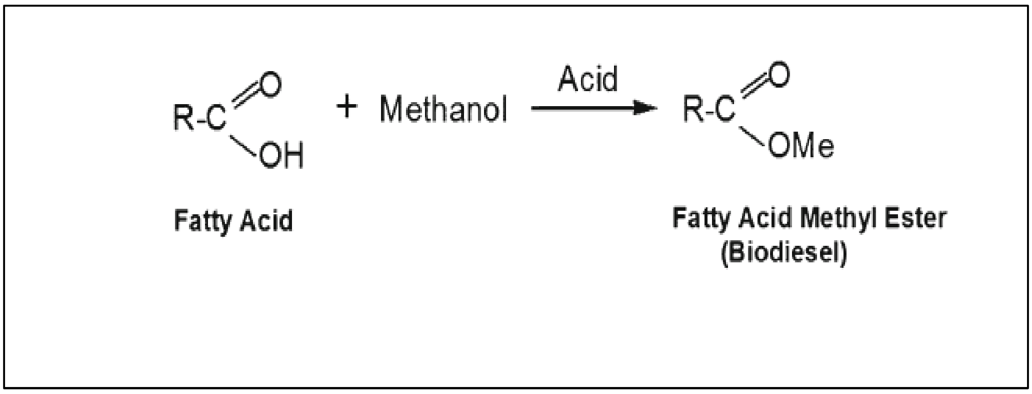

Fig. 5. Esterification of fatty acid present in Jatropha oils [50].

Although transesterification is the most important step in biodiesel production (since it originates the mixture of esters), pre-treatment of raw materials, alcoholic-catalyst mixing, chemical reaction, separation of the reaction products and purification of the reaction products are necessary to obtain a product that complies with international standards [47, 56]. The stepwise processes of processing Jatropha seed, extracting oil from same seed and transesterification of the oil to produce biodiesel was represented in Figure 6.

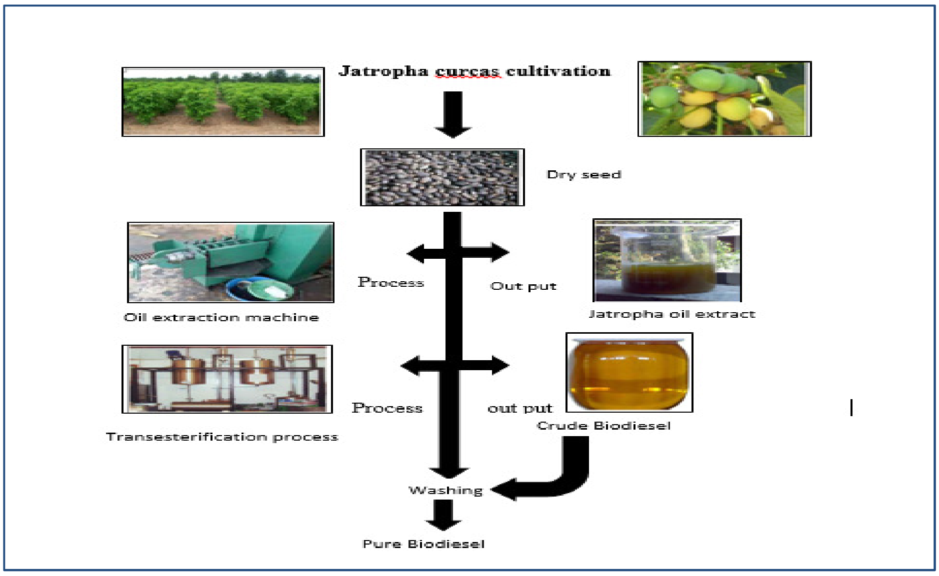

Fig. 6. Process flowchart for biodiesel production from Jatropha seeds and by products

In consequence, once the chemical reaction is completed and the two phases (mix of esters and glycerine) are separated as indicated in Figure 6, the mix of methyl esters must be purified to reduce the concentration of contaminants to acceptable levels. These include remnants of catalyst, water and methanol; the latter is usually mixed in excess proportion with the raw materials in order to achieve higher conversion efficiency in the transesterification reaction.

6. Characterization of biodiesel

Jatropha biodiesel has good fuel properties, comparable to or even better than petroleum diesel [51]. It has a higher flash point than diesel, making it a safer fuel. Other advantages are the almost zero sulfur content and the reduced amount of carbon monoxide, unburned hydrocarbons and particulate matter in the exhaust. But there are a few technical issues that need to be resolved. Biodiesel has a high viscosity at low temperatures, leading to flow problems at these temperatures. The fuel properties of biodiesel from Jatropha oil as shown in Table 4 were compared with standard as reported by [51]

Table 4
Fuel properties of Jatropha oil and Diesel

Properties	Unit	Jatropha oil methyl ester (Biodiesel)	Diesel	ASTM D6751-2 Standard	Test Method
Density	kg/m^3	880	850	875-900	D1298
Viscosity at 40°C	mm^2/s	4.84	2.6	1.9-6.0	ASTM D445
Flash point	°C	162	70	>130	-
Pour point	°C	-6	-20	-	-
Cetane number	-	51.6	40	-	-

Source[51].

Flash point: Flash point is a measure of flammability of fuels and thus an important safety criterion for transport and storage. The flash point of diesels is half of that of biodiesel fuels and therefore it represents an important safety asset for biodiesel. The flash point of Jatropha oil biodiesel is considerably higher than pure biodiesels, but within the prescribed limits. But can decrease rapidly with increasing amount of residual alcohol [5, 23].

Viscosity: The kinematic viscosity of biodiesel from Jatropha oil is higher than that of diesel and in some cases, at low temperatures biodiesel can becomes very viscous or even solidified. High viscosity can affect the volume flow and injection spray characteristics in the engine. At low temperature it may even compromise the mechanical integrity of the injection pump drive systems [52, 53].

Cloud Point: The behavior of automotive diesel fuel at low ambient temperatures is an important quality criterion, as partial or full solidification of the fuel may cause blockage of the fuel lines and filters, leading to fuel starvation, problems of starting, driving and engine damage due to inadequate lubrication. The melting point of biodiesel products depends on chain length and the degree of saturation, where long chain of saturated fatty acid esters displaying unfavorable cold temperature behavior [54].

Cetane number: The cetane number of a fuel describes its tendency to combust under certain conditions of pressure and temperature. High cetane number is associated with rapid engine start and smooth combustion. On the other hand, low cetane number causes deterioration in combustion behavior and higher exhaust gas emission of hydrocarbons and particulate. In general, biodiesel from Jatropha oil has a slightly higher cetane numbers than fossil diesel. Cetane number increases with increasing length of fatty acid chain and ester groups, and is inversely related to the number of double bonds [55].

7. Prospect of biodiesel development from Jatropha feedstock

The prospects of biodiesel development are enormous and vital to the speedy development of the nation economy. These benefits include the following:

- Production of biodiesel from Jatropha can lead to development of new industries, new jobs, new markets, new technologies
- Biofuel generates fewer emissions of carbon monoxide, particulates, and toxic chemicals (that cause smog, aggravate respiratory and heart diseases [56]
- Biodiesel from Sunflower, Canola, Jatropha can be used as a substitute for or as an additive to diesel fuel thus providing an alternative source of energy for diesel-powered engines.
- Biodiesel produces 80% less carbon dioxide and 100% less sulfur dioxide emissions, provides 90% reduction in cancer risk.
- Biodiesel is an oxygenated fuel, containing a reduced amount of carbon and higher hydrogen and oxygen content than fossil fuel.
- Biodiesels are renewable energy and can drastically reduce greenhouse gases since its production and use is nearly carbon neutral. It can be gotten from various sources including algae making its prospects almost limitless. It leads to improved demand for raw materials

8. Conclusion

The potentials of Jatropha as feedstock for biodiesel production and processes involve in biodiesel production are extensively discussed. The paper also highlighted various benefits for the use of biodiesel from Jatropha feedstock as an alternative energy to petroleum diesel, especially in the area of environmental sustainability, agricultural benefits, poverty alleviation, and more importantly improve economic development for rural communities. Moreover, as the world battles with the challenges of global economic recession, an alternative and environmentally responsible fuel such as biodiesel and its technology should be vigorously pursued, which on a longer term will help immensely in actualizing the Nigerian vision 2020 and grossly reduce the effect of climate change. Nigerian biofuel policy needs to focus on the increase use of vast arable land to promote environment friendly biofuels. Jatropha biodiesel may be a turning point in improving the living standards of the rural poor as such, proper credit mechanism needs to be developed to help small farmers to cultivate and sell this feedstock profitably. Therefore, authorities in Nigeria should appreciate these huge renewable energy potentials of Jatropha by reviewing the existing biofuel policies for sustainable development.

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