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Review article

HARNESSING BIOFUEL AND ECONOMIC POTENTIALS OF *JATROPHA CURCAS* FOR SUSTAINABLE DEVELOPMENT IN NIGERIA: A REVIEW

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Abstract

Nigeria has a lot of potentials of non-edible oil tree born seeds. The country is endowed with a lot of species of tree born-non-edible oil seeds which can be exploited for production of renewable energy to meet her energy needs. Energy crises have augmented research in newer thrust areas, resulting in finding out alternative fuels for meeting the energy demands of the developing sectors. Therefore, there is a need to explore the possibility of deriving energy from various alternative sources. *Jatropha curcas* plant is a better candidate, because it is a robust energy plant with many attributes and considerable potentials but underutilized in Nigeria. The wood, whole fruit, whole nut, coal, shell, kernel, wood charcoal, shell charcoal, plant oil, seed cake provides energy (oil for biodiesel, soap making, lubrication, seed cake for biogas, fertilizer (detoxified), soil improver e.t.c. The *Jatropha curcas* plant has many medicinal benefits and can be used to reclaim land, as a hedge and/or as a commercial crop. The plant has strong potentials for job creation and can serve as sources of revenue to the government if properly harnessed. Creating industry in the use of oil from *Jatropha* can help tackle youth idleness, thereby creating employment for the youths. Our current knowledge of *Jatropha curcas* plant in Nigeria is inadequate and therefore, this paper reviews the wonders of *Jatropha curcas* as bioenergy plant, industrial and medicinal applications and various economic benefits.

Keywords: Biodiesel, Biogas, Employment, *Jatropha curcas*, Renewable Energy

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Introduction

The increased dependence of petroleum products in Nigeria has no doubt created an unfortunate scenario of lapses and setback to national development. Prior to the 1970s, agricultural exports were Nigeria's main sources of foreign exchange. During this period, Nigeria was a major exporter of cocoa, cotton, palm oil, palm kernel, groundnuts and rubber. Government revenues also depended heavily on taxes on these exports. According to Osuntogun *et al*. (1997), between 1970 and 1974, agricultural exports as a percentage of total exports declined from about 43% to slightly over 7%. From the mid 1970s, the average annual growth rate of agricultural exports declined by 17%. The major cause of this development was the oil price shocks of 1973-1974 and 1979, which resulted in large receipts of foreign exchange by Nigeria and the neglect of agriculture.

As of 2012, there were 37.2 billion barrels (5.91 x 10^9 m^3) of proven oil reserves in Nigeria, ranking the country as the largest oil producer in Africa (although Libya has more reserves) and the 11th largest in the world, averaging 2.28 million barrels per day (362 x $10^3 m^3$/d) in 2006. Pipeline vandalism, kidnappings, and militant activities around oil facilities have reduced production. Nigeria is the world's eighth largest exporter of crude oil and the country is heavily dependent on the oil sector (Wikipedia: Oil reserves in Nigeria). Enormous as Nigeria oil reserves may appear, known crude oil reserves are depleting fast, coupled with its unstable and rising cost, and environmental problems (Kumar & Sharma, 2005; Chhetri *et al.,* 2008; Akbar *et al.*, 2009; Padhi & Singh, 2010; Madarasz & Kumar, 2011; Aransiola *et al.*, 2012; Izah and Ohimain, 2013) and these have motivated researchers more extensively to seek alternative renewable sources. An alternative fuel to petrodiesel must be technically feasible, economically competitive, environmentally acceptable and easily available (Dermibas, 2009; Rao *et al.,* 2009; Lateef *et al.*,2014). Biomass residues seem to be a better alternative. Biomass residues can be converted into various non-solid fuel forms. These fuels are referred to as biogas and liquid biofuels (bioethanol, biodiesel e.t.c.).

In developed nations (e.g. Europe and United States) as well as several developing countries, there is intense effort towards cultivating energy crops specifically for the production of biomass as a fuel. The potential for energy production from biomass throughout the world is enormous. Biofuels (biogas, biodiesel, bioethanol) from biomass sources are currently being recognized globally as renewable energy sources as it provides relatively cheaper sources of energy for cooking, heating, lighting, vehicular and engine operation fuel. Non-edible oil from *Jatropha* and seed cake can be used to provide the needed energy, although other crops such as palm kernel oil, soybean, palm peanut, and variety of less common oils also show great potential as sources of raw material for biofuel production (Baroutian *et al.,* 2008; Chhetri *et al*., 2008). Non-edible oil seeds (Castor, *Madhuca indica*,*Pongamia pinnata*) are in abundance in Nigeria.

Non-edible oils like Mahua (*Madhuca Longifolia*, *Madhuca indica*) (Padhi & Singh, 2010; Savariraj *et al*., 2011; Navindgi *et al*., 2012; Kulkarni *et al*., 2013*)*, *Moringa oleifera* oil (Anwar *et al*., 2008), Castor oil (Bello & Makanju, 2011; Sreenivas *et al*.,2011; Babu & Mamilla, 2012; Apita and Tenu, 2013), *Pongamia pinnata* (Karanja) oil (Naik *et al*., 2004; Bobade & Khyade, 2012; Savaliya & Dholakiya, 2012; Hameed *et al.*, 2012; Naik & Katpatal, 2013) and crude neem oil (Aransiola *et al*., 2012) have shown to be better biodiesel feedstock with good fuel properties in a compression ignition (CI) engine. *Jatropha curcas* has received much attention because of its immense role in biodiesel production – an eco-friendly fuel, biodegradable, renewable and non-toxic in nature compared to petrodiesel (Pandey *et al*., 2012). The oil from Jatropha plant is considered as the best source of biofuel (diesel fuel) production among the various plants based fuel resources the world over (Belewu *et al*., 2010).

Considering the future scenario of non-edible oil seed utilization, there is need for efficient utilization of their cakes. The oil seed cake can neither be used for animal feeding nor directly can be used in agricultural farming due to its toxic nature. The generation of biogas from these cakes would be a best solution for its efficient utilization which provides energy for cooking, heating, lighting and engine operations. Nigeria has a lot of potential of non-edible oil tree born seeds, which can be exploited for production of renewable energy to meet her energy needs of which *Jatropha curcas* is a better candidate.

With the present Nigeria rising population, one of the ways to create wealth or reduce poverty and unemployment is to promote agriculture. Kidnapping, armed robbery, militancy in some parts of the country and the *Boko Haram* menace could be identified as some of the negative outcomes of unemployment. Therefore, creating industry in the use of oil from *Jatropha* can help tackle youth idleness, thereby creating employment for the youths.

Jatropha curcas seeds are rich in oil used as biofuel which makes this plant an important subject for research into renewable energy (Habou *et al*., 2011). The *Jatropha curcas* plant (JCP) is currently receiving a great deal of attention. JCP has been recognized as a source of a medium viscosity pure plant oil that is easily converted to biodiesel with good product properties and have been tested successfully in stationary diesel engines (Openshaw, 2000; Manrung *et al*., 2009). *Jatropha* oil cannot be used for edible purposes without detoxification, making it attractive for biodiesel production. The non-consumptive utilization of the plant will facilitate the protection of environment and ensure faster and durable greening of the country, help to conserve the soil, water and provide permanent renewable source of energy (Hipal *et al.,* 2009).

The seed kernel of the plant contains up to 60% oil, which can be transesterified to biodiesel (Makkar *et al*., 2012). *Jatropha curcas* plant is a robust energy plant, which in addition to seed oil, also produces wood, fruit shells, seed husks and press-cake. These are potential sources of additional energy carriers in a zero-waste bioenergy system for *Jatropha curcas*. Several energy conversion technologies can be used to derive solid, liquid and gaseous energy carriers for *Jatropha curcas* and the by-products of its processing. The technologies include anaerobic digestion, pyrolysis, gasification, transesterification and combustion (Jingura *et al.*, 2010). Manrung *et al.* (2009) have provided the proof of principle for the conversion of *Jatropha curcas* nut shells by a fast pyrolysis process to pyrolysis oil. The non-optimized pyrolysis yield was 50 wt %, the remainder being char (23 wt %) and gases (17wt%). Fast pyrolysis may become an essential element in *Jatropha curcas* biorefineries to valorize the nut shells into fast pyrolysis oil, a promising second generation biofuel which may be used on site for energy generation (for example,boilers) or transportation fuel, and also produces a char-sand mixture which is rich in minerals and has potential as a solid improver (biochar). The gaseous components may be used for energy generation as bulk chemicals synthesis.

Jatropha curcas is a nut belonging to the *Euphorbiaceae* family, which originated in Central America, but widespread in West and Central Africa countries (Kumar & Sharma, 2008; Habou *et al.*, 2011; Nabil *et al*., 2012; Abdul Khalil *et al*., 2013). It is a plant with many attributes, multiple uses and considerable potential (Openshaw, 2000; Sachdeva *et al.*, 2012). *Jatropha curcas* tree can easily be propagated by cutting and is widely planted as a hedge to protect the field’s erosion.It is drought resistant and can grow in gradually sandy saline soil. This plant can grow up to 8 meters, it has large green to pale green leaves and can produce seeds up to 35 years (Mohammed *et al*., 2012). The seed of *Jatropha*is oval in shape and black in colour. The oil produced from the seed of *Jatropha* is golden yellow in colour.

The genus *Jatropha* contains approximately 175 known species. The genus name *Jatropha* derived from the Greek words *jatros* (doctor), *trophe* (food), which implies medicinal uses. *Jatropha curcas* thrives in poor, stony soils and under adverse climatic conditions. The *Jatropha curcas* fruit is made up of a green epicarp, a flesh mesocarp and hard endocarp. It is very abundant in the country (Nigeria). It has numerous common names depending on the country where it is found, but is most commonly referred to as physic nut or purging nut (Openshaw, 2000). *Jatropha curcas* is known in Nigeria by various local names as “Lapalapa”, “Kekene”, “Butuje”, “Ologbo” e.t.c.

Jatropha: Cultivation, Production in Nigeria and the World

Although, *Jatropha* grows naturally in Nigeria, its cultivation on an economic scale is a recent venture for which little reliable scientific data exists either for environmental assessment/management or as bioenergy crops for biofuel production; therefore, the *Jatropha* industry is in its early stage. More than 85 percent of *Jatropha* plantings are in Asia, chiefly Myanmar, India, China and Indonesia. Africa accounts for around 12 percent, mostly in Madagascar and Zambia (FAO, 2010). Also, estimation of planted *Jatropha* in Tanzania is 17,000 ha which is 1.9% of the global cultivation and 14.4% of the total cultivation in Africa (Mkoma & Mbaki, 2012). Tanzania is considered very important for *Jatropha* cultivation sector with an estimate of up to 69,870 ha in 2010 to 620,110 ha in 2015. Globally, the area planted to *Jatropha* is protected to grow to 4.72 million ha by 2010 and 12.8 million ha by 2015. By then, Indonesia is expected to be the largest producer in Asia with 5.2 million ha, Ghana and Madagascar together have the largest in Africa with 1.1 million ha, and Brazil is projected to be the largest producer in Latin America with 1.3 million ha (GEXsi, 2008); but *Jatropha* cultivation and production system information is lacking in Nigeria. Though large scale cultivation, production of *Jatropha* has been embarked upon by Nigeria government in some northern states – Adamawa, Katsina, Kano, Gombe, Borno, Bauchi, Yobe, Jigawa, Zamfara, Sokoto, and Kebbi.

Oil Extraction

There are two ways (methods) that can be employed for oil extraction; squeezing or mechanical pressing and chemical solvents. For *Jatropha,* choosing efficient extraction methods can increase the yield by 10% (Padhi & Singh, 2011). Solvent extraction gives higher yield and less turbid oil than mechanical extraction, and relative low operating, compared with superficial fluid extraction (Amin *et al*., 2010).

Uses of *Jatropha Curcas* Plant

The end uses for *Jatropha curcas* plant are discussed below:

2.1 Biodiesel

Biodiesel from vegetable oils is synthesized by the method of transesterification reaction. But there are certain exceptional cases wherein direct transesterification cannot be performed especially in non-edible oils like *Jatropha*, Mahua, Neem, Castor and Karanja e.t.c. Oils of high free fatty acids content can be converted into biodiesel via dual step transesterification process (Bobade *et al.,* 2013). In the first step, the oil is treated by an acid dissolved in an alcohol to reduce free fatty acid content, whereas in the second step, the pre-treated oil is transesterified with an alcohol in the presence of base catalyst to form ester and glycerol. High free fatty acid above 1% w/w yields low biodiesel production but favours the production of soap (Nakpong & Wootthikanokhan, 2010; Ogunleye & Eletta, 2012; Shrestha *et al.*, 2013 Baroi *et al.*, 2009; Deng *et al.*, 2011, Highina *et al.*, 2011). The free fatty acid amount of *Jatropha curcas* oil will vary and depend on the quality of feedstock.

The high free fatty acid content (> 1% w/w) gives soap formation and the separation of products will be exceedingly difficult. The acid-catalyzed esterification of the oil is an alternative, but it is much slower than the base-catalyzed transesterification reaction (Berchmans & Hirata, 2008; Mathiyazhagan *et al*., 2011; Endalew *et al*., 2011; Bojan & Durairaj, 2012). The high free fatty acid content of oil samples-consumes the catalyst to form soap, soap formation in turn reduces the catalyst effect leading to gel formation and that makes the separation of the glycerol from product difficult. Single step simultaneous esterification and transesterification using heterogeneous catalysts, have been advocated by researchers (Endalew *et al.*, 2011), because they reasoned that two-step method increases system complexity and the cost of production. In heterogeneous catalysis, contrary to the homogenous catalysis adsorption of reactants and desorption of products have to take place on the surface of the solid catalyst for the reaction to take place at increased rate. Therefore, the use of heterogeneous catalysts have been presented by various researchers in literature. These catalysts includes zeolites, clays, mesoporous silica, heteropolyacid, resins and inorganic oxides (Mazutti *et al*., 2013). Other methods of biodiesel production from *Jatropha curcas* oil using ultrasonic irradiation assisted (Worapun *et al*., 2010) and conventional heating (Roces *et al.*, 2013) have been reported with promising results.

Two approaches for transesterification of Jatropha curcas oil for biodiesel has been reported: chemical one using alkali catalyst (NaOH, KOH or alkoxides) or acid catalyst(strong acids H_2SO_4, H_3PO_4). The product of the reaction is a mixture of esters, which is known as biodiesel and glycerol, which is a high value co-product. The second approach is the enzymatic approach (Banerjee *et al*., 2009; Nahak *et al*., 2010). Biodiesel from vegetable oils can be prepared with or without catalyst. Non-catalytic transesterification of biodiesel may be accomplished in supercritical fluids such as methanol, but a very high pressure (45-65 bar), temperature (350^oC) and amount of alcohol (42:1 molar ratio) are required (Moser, 2009).The advantages of superficial versus various catalytic methods are that only very short reaction times (4 min, for instance) are needed, and product purification is simplified because there is no need to remove a catalyst. Disadvantages of this approach include limitation to a batch-wise process, elevated energy and alcohol requirements during production, and increased capital expenses and maintenance associated with pressurized reaction vessels (Demirbas, 2009; Lateef, 2010).

Despite *Jatropha curcas* oil enormous potentials as biofuel plant (especially for biodiesel production),a few studies by Nigerian researchers such as Belewu *et al.* (2010); Adebayo *et al.* (2011); Oghenejoboh and Umukoro (2011); Highina *et al*. (2011); Ojolo *et al.* (2011), Muazu *et al.* (2012); Aransiola *et al*. (2012); Ogunleye and Eletta (2012); Olawale *et al*. (2012); Ayoola *et al*. (2013); and Efeovbokhan *et al*., have been reported in peer-reviewed journals.

Current Status of Biofuel in Nigeria

In line with August 2005 government directive on biofuel, the country released the Nigerian Biofuel Policy and incentives in 2007 which mandated the Nigerian National Petroleum Corporation (NNPC) to receive and blend 20% of biodiesel into the petro-diesel fuel sold in Nigeria, with the aim of linking the agricultural sector with the petroleum sector in order to boost the agricultural and rural sector. Incentives included in the policy for emerging biofuel companies included waivers (VAT, withholding and import duty), loans, and insurance coverage (Galadima *et al*., 2011; Izah & Ohimain, 2013). Despite this, biodiesel production in Nigeria is at infancy and that account for non-inclusion of Nigeria in the top 10 countries in terms of biodiesels potential and global production of biodiesel as inTable 1 and Table 2.

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Table 1: Top 10 Countries in Terms of Biodiesel

Rank	Country	Potential biodiesel (ml)	Production ($/l)
1.	Malaysia	14,540	0.53
2.	Indonesia	7,575	0.49
3.	Argentina	5,255	0.62
4.	USA	3,212	0.70
5.	Brazil	2,567	0.62
6.	Netherlands	2,496	0.75
7.	Germany	2,024	0.79
8.	Philippines	1,234	0.53
9.	Belgium	1,213	0.78
10.	Spain	1,073	0.71

Source: Patel and Krishnamurthy (2013)

Presently, Nigeria government has shown great interest in *Jatropha* plant and other biofuel plants. The aim is to gradually reduce the nation's dependence on imported gasoline, reduce environmental pollution as well as create commercially viable industry. Large scale cultivation and production of *Jatropha* has been embarked upon by Nigerian government in some northern states such as Adamawa, Gombe, Borno, Bauchi, Yobe, Katsina, Kano, Jigawa, Zamfara, Sokoto and Kebbi.

Table 2: Global Production of Biofuel

Country	Number of Plants	Location	Total Annual Capacity, tonnes	Oils used
Austria	(1)	Aschach, Bruck, Pischeldorf	56,200-60,00	Used-frying oil
Belgium	3	Feluy, Seneffe	241,000	–
Canada	1	Saskatoon		
Czechoslovakia	17(1)	Mydlovary, Olomouc	42,500 – 45,000	User-frying oil
Denmark	3	Otterup, Jutland	32,000	–
France	7(1)	Rouen, Compiegne, Boussens, Nogentsurscine	38,100	–
Germany	8(4)	Leer, Dusseldorf, Kiel, Barby, Germunden, Thuringia	207,000	–
Hungary	17(6)	Visnye, Gyor	18,880	–
Ireland	(1)		5,000	Used-frying oil
Italy	9(4)	Livomo, Cittadi, Casleto, Milano, Solbiate, Napoli, Bari, Ancona, Brescia	779,000	Sunflower oil
Nicaragua	1	–	–	*Jatropha* oil
Slovak Republic	10(1)	Barcelona	50,500 – 51,000	–
Spain	1	Bilbao	500	–
Sweden	3(1)	Gothenborg,Skane	75,000	–
Switzerland	1	Geneva	2,000	–
U.K	1	East Dusham	–	–
U.S.A	4(3)	Midwest, Chicago, Quincy	190,000	Used-frying oil
Yugoslavia	2	–	5,000	–

Source: Srivastava and Prasad (2000)

Up till now, research effort to source for alternative source of energy is still very much at infancy in Nigeria. Most researchers in Nigeria reported on the use of edible vegetable oils for biodiesel production (Alamu *et al*., 2008; Opara & Obot, 2009; Bello *et al.*, 2011). However, as the biodiesel is produced from Nigeria edible oils, there are concerns that biodiesel feedstock may compete with food supply in the long term. Hence, the recent focus is to find oil bearing plants that produce non-edible oils as the feedstock for biodiesel production. Second generation feedstock that have high potential in Nigeria is *Jatropha.* It is not edible and does not compete with food.

Advantages of Biodiesel

Biodiesel derived from vegetable oils, is the most promising alternative fuel to conventional or petrodiesel due to the following reasons.

1. Biodiesel provides a domestic renewable energy.It is environmental friendly (as it does not contribute to global warming), portable, readily available, higher combustion efficiency, lower sulphur and aromatic content (Demirbas, 2009).
2. Biodiesel can be used in the existing engine without any modification.Its use can extend the life of diesel engines because it is more lubricating that petroleum diesel fuel (Hanumantha *et al*., 2009; Parawira, 2010; Bobade *et al.,* 2013).
3. Other advantages include reducing a given economy's dependency on imported petroleum, thus ensuring energy security, biodegradability, higher flash point, non-toxic and non-flammable liquid.

Disadvantages of Biodiesel

Biodiesel is more expensive to petrodiesel and the blends of biodiesel above 20% can cause engine maintenance problems and even sometimes damage the engine in the long term. Other disadvantages include higher viscosity, higher cloud point and pour point, higher nitrogen oxide (NOx) emissions, lower engine speed and power, injector cooking, engine compatibility (Demirbas, 2009; Parawira, 2010).

Benefits of Pre-treatment

The pre-treatment of oils and fats is one of the most important criteria for the production of high-quality biodiesel. Crude plant oils contain some free fatty acids and phospholipids, so it is important to pre-treat the feedstock. *Jatropha curcas* oil is among the crude plant oils with high free fatty acids (FFA). The benefits of pre-treatment include:

1. No contamination – better glycerine quality
2. No gums which might result in caking in the thermal glycerine process
3. No phosphates in the waste water-reduced disposal costs.
4. No free fatty acids
5. No waxes – higher cold stability of the biodiesel

Disadvantages of vegetable oils as diesel fuels are: higher viscosity, lower volatility and the reactivity of unsaturated hydrocarbon chains. Vegetable oils have their own advantages; first of all, they are renewable as the vegetables which produce oil seeds can be planted year after year. Secondly, they are available everywhere in the world. Thirdly, they are "greener" to the environment, as they seldom contain sulphur element in them (Balat & Balat, 2008).

Relying on fossil fuel alone is no longer realistic due to global depletion of the non-renewable energy sources, its attendant negative environment impact. The race for energy security in the face of imminent oil shortage is already gathering momentum. Countries in Asia, Europe, South American and many US state governments are not waiting for their fossil fule to dry up completely before searching for alternatives. It is only countries that don't value their own security and that of their citizens would stand aloof. A lot of work can be done to reduce the cost of biodiesel if we consider non-edible oils, used frying oils, instead of edible oils. Non-edible oils such as *Jatropha, Karanja, Neem* e.t.c. are readily available in Nigeria and are very cheap. With the growth of fast food centers and restaurants in Nigeria, it is expected that considerable amount of used frying oils would be discarded. This can be used for making biodiesel.

All potential feedstock for biofuel (biodiesel, biogas) production are in abundance in Nigeria. The country with her expansive arable land mass can be one of the world's leading exporters of biodiesel, if the governments puts a premium on energy security like many countries (such as US and some European countries) are now doing. A well defined road map should be put under implementation by the government of Nigeria so that commercial use of biodiesel will be implemented in the mega cities and subsequently spread over the country. However, there are fears that since biodiesel relies on primary agricultural products, a substantial growth in the biodiesel industry could make the prices of vegetable oil unaffordable to the common man. Hence, our approach to renewable energy sources should be focused on non-edible oils such as *Jatropha.*

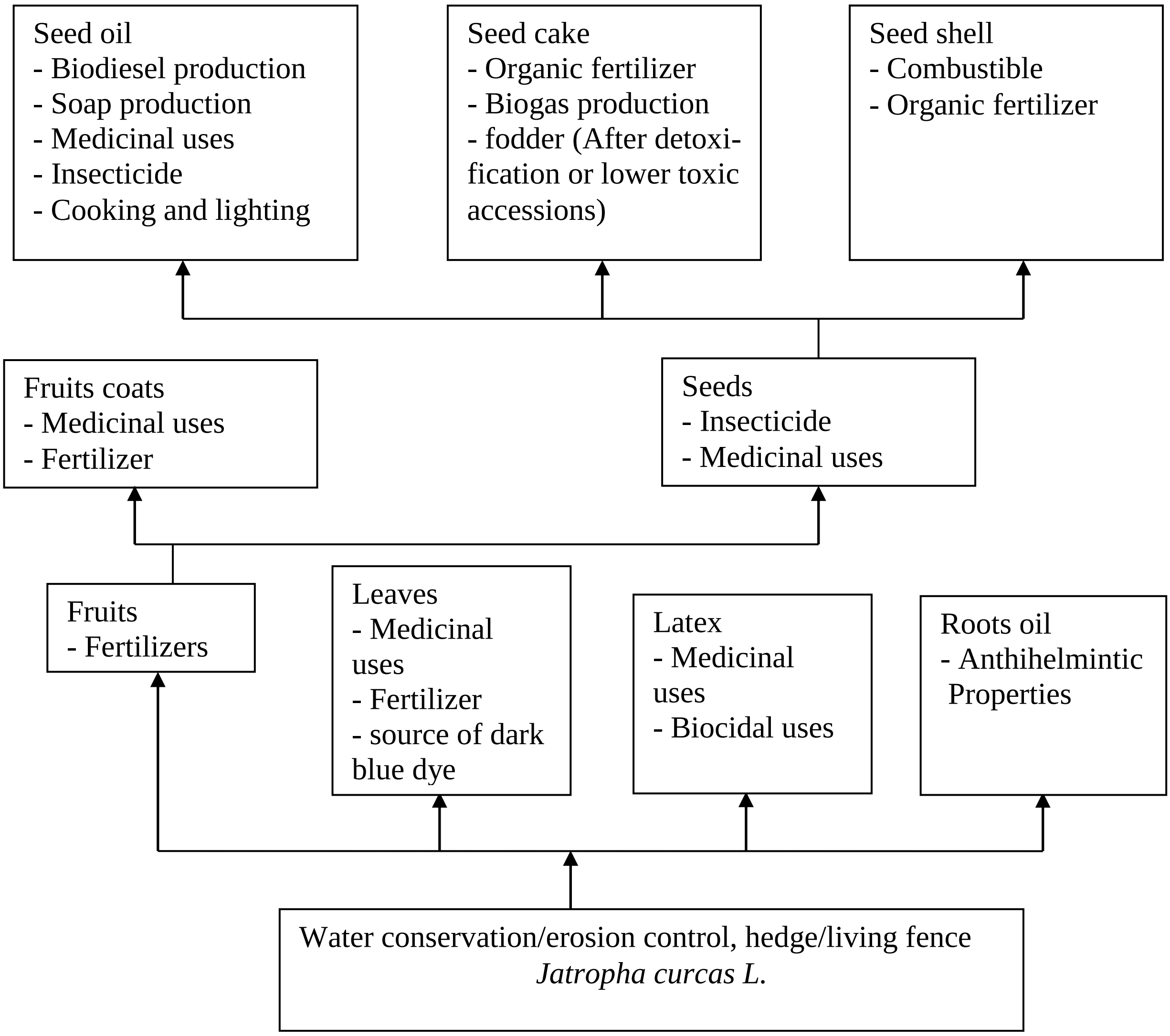

Figure 1: Uses of *Jatropha curcas* components (Adapted from Parawira, 2010)

2.2 Biogas

Aside considering *Jatropha curcas* oil for biodiesel production and soap making (and other various uses) as its most market value, utilization of *Jatropha* oil cakes as an energy source in the production of methane-rich biogas is under examination by various scientific researchers. Chandra *et al.* (2006) reported biogas generation from *Jatropha curcas* and *Pongamia pinnata* oil seed cakes with promising results which shows biogas generation potential in the range of 220-250 and 240 – 265 litre per kg of cake respectively under mesophilic temperature range of anaerobic digestion with methane content in the range from 65 – 70% against 55% from cattle dung. The study revealed that biogas production from non-edible oil seed cakes is a simple method of cake disposal and to obtain self-sufficiency in meeting rural energy need.

Energy values, potential end uses and other possible uses of various fuels from *Jatropha* are shown in Tables 3 and 4.

Table 3: Energy Value of Various Fuels from *J. curcas*

Fuel	Ash content (%)	Moisture	Energy value	Composition of the fruit (%)			Recovery percentage
				Coat	Shell	Kernel	
Wood	1	15	15.5				95 – 100
Whole fruit	6	8	21.2	30	24	46	95 – 100
Whole nut	4	5	25.5	0	34	66	67 – 70
Coat	13	15	11.1	100	0	0	28 – 30
Shell	5	10	17.2	0	100	0	23 – 24
Kernel	3	3	29.8	0	0	100	44 – 46
Wood charcoal	3	5	30.0				15 – 25
Shell charcoal	15	5	26.3				15 – 25
Plant oil	< 0.1	0	40.7				11 – 18
Seed cake	4	3	25.1				29 – 35

Source: Openshaw (2000)

Table 4: Potential End-Uses of Fuels from *J. curcas*, plus Other Possible Uses

Fuel type	Free (F) or For Sale (S)	End use of Fuel	Other Possible Uses
Small branches and twigs	F	Rural household (H/h) cooking. May be difficult to burn because remain green for long period	Bean sticks, planting and fencing material
Large branches and stem	F & S	Rural and urban H/h cooking. Service sector and industrial use-tobacco barns, brick stacks, boiler fuel, cooking in schools e.t.c.	Building poles, fence posts, charcoal production
Whole fruit	F & S	Rural and urban H/h cooking. Service and industrial uses -tobacco barns, brick, bakeries, fuel, schools e.t.c	Ash used as a fertilizer
Whole nut	F & S	Rural and urban H/h cooking. Service and industrial uses-tobacco, brick, bakeries, boilers, schools e.t.c.	Ash used as a fertilizer
Exocarp (coat)	F	Rural H/h cooking	Soil improver
Shell	F & S	Rural H/h cooking, industrial use- tobacco, brick, boilers e.t.c.	Soil improver, charcoal production
Kernel	F & S	Rural H/h cooking, industrial use- tobacco, brick, boilers e.t.c.	Animal feed (if treated). Planting materials.
Wood charcoal	S	Urban H/h and non- H/h cooking	Fine as soil conditions
Shell charcoal	S	Urban H/h non-H/h cooking	Activated charcoal
Plant oil	S	Urban cooking, urban and rural lighting, service sector and industrial uses, diesel and kerosene substitute or extender	Soap making, lubrication oil, cosmetics, medicine, cooking oil (detoxified)
Seed cake	F & S	Urban H/h and non-H/h cooking, boiler fuel	Fertilizer, animal feed (if treated)

Source: Openshaw (2010)

The literature survey shows non-availability of information on the direct biomethanation of *Jatropha curcas* oil seed cake in Nigeria. Although Jatropha grows naturally in Africa, its cultivation on an economic scale is a recent venture for which little reliable scientific data exists either for environmental assessment or management (Mkoma & Mabiki, 2012).

Prateek *et al*. (2012) reported biomethanation potential of *Jatropha curcas* cake alongwith buffalo dung at 6% total solids. The experiment was ran on daily feeding basis in 5-litre capacity glass digester for 180 days, while biogas production was recorded at 24 hours interval. Quality of biogas and nutritive value of effluent slurry was also determined. Results show significantly higher (139.20%) biogas production in test *(Jatropha* cake + Buffalo dung) over control (Buffalo dung only) digesters with methane content of 71.74%. Nutritive value of effluent slurry of test digesters was significantly higher in terms of available nitrogen and potassium, calcium, magnesium and carbonate contents than that of control digesters. Co-digestion results in 92.94% decrease in chemical oxygen demand.

Gupta *et al*. (2009) also reported batch anaerobic digestion of substrates of *Jatropha* and *Pongamia* oil cake and mixtures with cattle dung (1:1, oil cake: fresh cattle dung) in aspirator bottles for 60 days hydraulic retention time. Most productive biogas yield corresponds to mixture of *Jatropha* cake and *Pongamia* cake co-digested with 50% cattle dung, having dilution ratio of 3.5 – 4 with former mixture giving highest daily biogas yield.

Similarly, promising results was reported by Vijay *et al*. (2008) on the production of methane through anaerobic digestion of *Jatropha* and *Pongamia* oil seed cakes. Though, there are several scientific reports on biogas production by Nigerian scientific researchers, none have been reported on *Jatropha curcas* seed cake in a peer-reviewed journal. Uzodinma and Ofoefule (2009) reported biogas production from blends of field grass (*Panicum maximum*) with some animal wastes; Igoni *et al*. (2008) reported effect of total solids concentration of municipal solid waste on the biogas produced in an anaerobic continous digester. Adelekan and Bamgboye (2009) reported comparison of biogas productivity of cassava peels mixed in selected ratios with major livestock waste types. Iyagba *et al*. (2009) reported the study of cow dung as a co-substrate with rice husk in biogas production; Oyewole (2010) reported biogas production from chicken dropping; Ngozi-Olehi *et al.* (2010) reported kinetics of biogas potential from animal and domestic waste; Bolarinwa and Ugoji (2010) reported production of biogas from starch wastes; Ofoefule and Onukwuli (2010) reported biogas production from blends of bambara nut (*Vigna subterranea*) chaff with some animal and plant wastes; Abdullahi *et al*. (2011) reported effect of kinetic parameters on biogas production from local substrate using a batch feeding digester; Yussuf *et al*. (2011) reported ambient temperature kinetic assessment of biogas production from co-digestion of horse and cow dung; Ofoefule *et al*. (2011) reported effect of chemical pretreatment and waste blending on biogas production from leaf litter of Kambala (*Chlorophoral excelsa*); Eze and Ojike (2012) reported anaerobic production of biogas from maize wastes; Okareh *et al*. (2012) reported enrichment of pig dung with selected crop wastes for the production of biogas; Ukpai and Nnabuchi (2012) reported comparative study of biogas production from cow dung, cow pea and cassava peeling using 45 litres biogas digester; Ndinechi *et al.* (2012) reported economic potentials of animal dung as a viable source of biomass energy.

Nigeria is endowed with abundant agricultural resources out of which *Jatropha curcas*is one, of which the seed cake can be used for the production of biogas to meet its need for cooking, heating and lighting. In Nigeria, out of the total land area of 92.4 million hectares, 79.4 million and 13.0 million hectares are occupied by land and water respectively. Agricultural land occupies 71.9 million hectares. This indicates a high potential for agricultural production, a considerable proportion of which can be applied as feedstock in biofuel manufacture (Highina *et al*., 2012).

Current Status of Biogas Production in Nigeria

To address the various energy challenges associated with depleting fossil fuel reserves, many countries have indicated commitment to biofuels production. Biogas in particular, had become an important source of energy even in the rural communities. According to Abdullahi *et al.* (2011), there are currently about 135,000 biogas plants in Nepal. The scale of programme is remarkable. Biogas already serves about one million people (4% of the population of the Nepal), and the biogas sector provides about 11,000 permanent jobs in the country. India had an estimated two million plants in use in 2000. Biogas programme are growing in many parts of the world, such as Vietnam, Brazil, and Africa (Abdullahi, 2011; Ndinechi *et al.,* 2012). By 2010, the number of rural household biogas users had reached 41.8 million in China (Yongzhong *et al*., 2012).
All potentials feedstocks for biofuel (biogas) production are in abundance in Nigeria. The country with her expansive arable land mass can be one of the world's leading producers and exporters of biogas, if the government

puts a premium on energy security like many other countries such as US and some European countries are now doing. Presently, very few biogas units, operating mainly on a significantly low level of technology are available in Nigeria. In addition to energy security and waste management,biogas has strong potentials for job creation and source of revenues to the government.

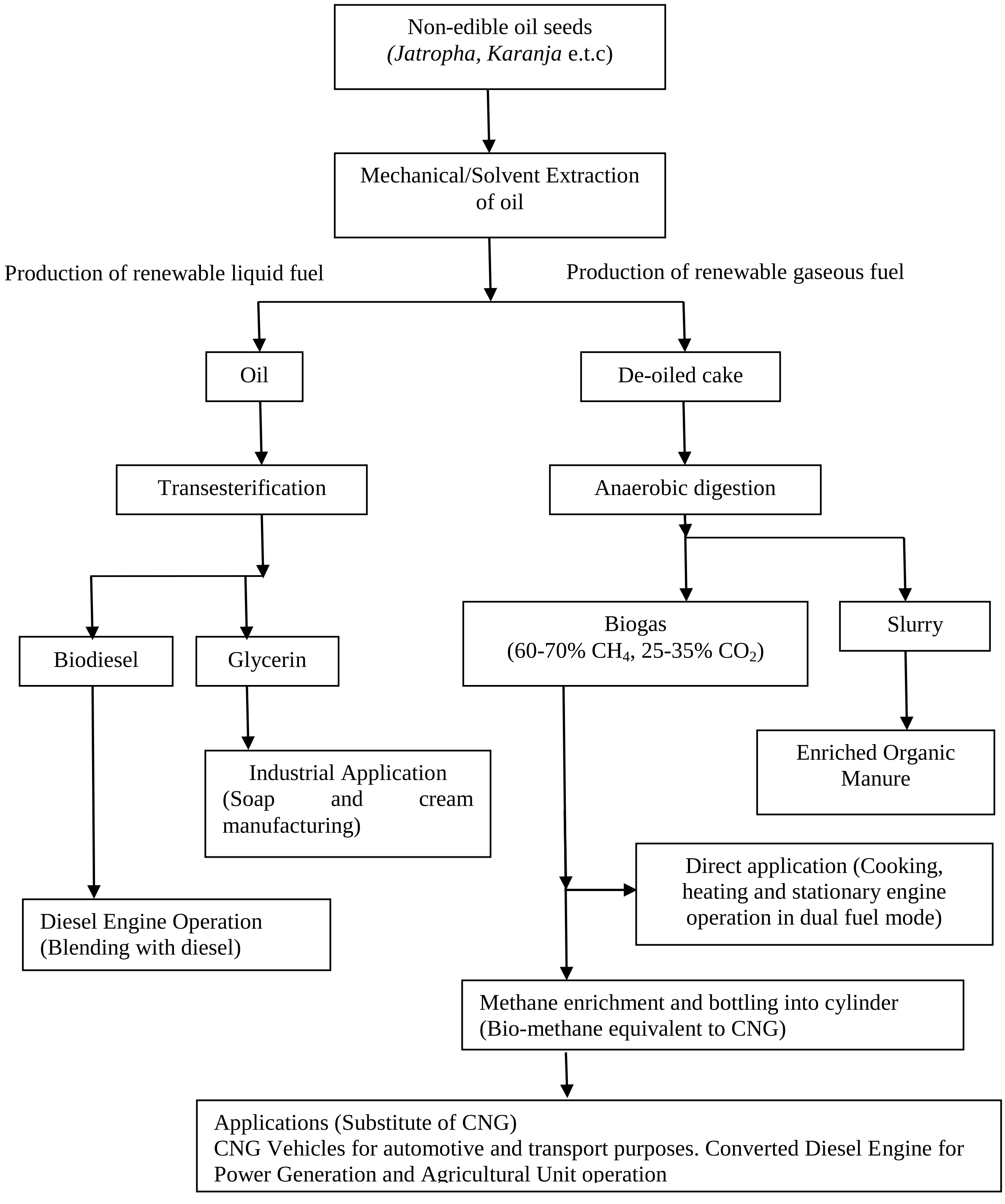

Figure 2: Schematic diagram showing utilization of non-edible oil seed for production of renewable liquid (biofuel) and gaseous (biogas) fuel. Source: Chandra *et al*. (2006)

Overview

Biogas is a term used to represent a mixture of different gases produced as a result of the action of anaerobic microorganisms on domestic and agricultural waste (Iyagba *et al*., 2009); which takes place in the absence of air in a special design biodigester. The digestion of domestic and agricultural wastes yields several benefits.

(1) Production of methane for use as a fuel for cooking, heating and lighting.
(2) The waste is reduced to slurry which has a high nutrient content which makes an ideal fertilizer for soil improver (in case of *Jatropha curcas*).
(3) Biogas systems can help in the fight against global warming by allowing the burning methane from organic wastes, instead of letting it escape into the atmosphere where it adds to the greenhouse effect.

There are four key biological and chemical stages of anaerobic digestion. Firstly, through the chemical reaction of hydrolysis, complex organic molecules contained within the feedstock of the digestion system are broken down into simple sugars, amino acids, and fatty acids. Secondly, the biological process of acidogenesis where there is further breakdown of the components of input by acidogens. Here volatile fatty acids are created along with ammonia, carbon dioxide and hydrogen sulphide as other byproducts. The third stage of acetogenesis is facilitated through microorganisms called acetogens. Here, the simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acetic acids, with carbon dioxide and hydrogen. The fourth and final stage of anaerobic digestion is the biological process of methanogenesis. Here, methane forming bacteria called methanogens utilize the product of the preceding stages and convert them into methane, carbon dioxide and water (Vijay *et al.*, 2008). Biogas is a colourless, flammable gas with the following composition: methane (50 – 70%), CO_2 (20 – 40%) and traces of other gases such as H_2S, NH_3, CO, N_2, H_2, O_2, water vapour e.t.c. (Ofoefule and Onukwuli, 2010).

2.3 Medicine

According to Manjunath *et al*. (2013), *Jatropha* plant has been used traditionally for medicinal purposes. The plant possesses anti-inflammatory, anti-mestastic, anti-tumor, coagulant and anti-coagulant (dose dependent), disinfectant, anti-parasitic, wound healing, insecticidal, pregnancy terminating activity and anti-diarrhoeal effect. Nabil *et al.* (2012) reported that the plant contains terpenes which have shown a wide range of biological activities – including molluscicidal, insecticidal and fungicidal activities. Cytotoxicity assay results of *Jatropha curcas* indicated the potential of its methanolic extract as a source of anti-cancer therapeutic agents toward breast cancer cells (Abdullahi *et al*., 2011).

Table 5: Various Medicinal Uses of *Jatropha curcas*

S/N	**Useable plant parts**	**Diseases curing**
1.	Seeds	To treat gout, arthritis and jaundice, wound-healing, fractures, burns, purge
2.	Seed oil	Eczema, skin diseases, soothe rheumatic pain, purgative action
3.	Stem	Toothache, gum inflammation, gum bleeding, pyorrhoea
4.	Stem bark	Infectious diseases, including sexually transmitted diseases
5.	Plant sap	Dermatomucosal diseases
6.	Water extract of branches	HIV, tumour
7.	Plant extract	Wound healing, allergies, burns, cuts and wounds, inflammation, leprosy
8.	Leaves and latex	Refractory ulcers, septic gums, styptic in cuts and bruises
9.	Latex	Reduced the clotting time of human blood, sore mouth, oral thrush, fish barb wounds, snake-bites, infected sores,treatingnewborns'umbilical cords, coughs, mouth and throats sores
10.	Root powder	In the treatment of inflammation
11.	Leaf	Scabies, Eczema, Syphilis, blood cleansing, headache, flu, cough, congestion, evil eye, cleansing house
12.	Fruit	Stroke, toothache, numbness after bug sting, to clean mother's and baby blood during the pregnancy

Source: Pandey *et al*., (2012)

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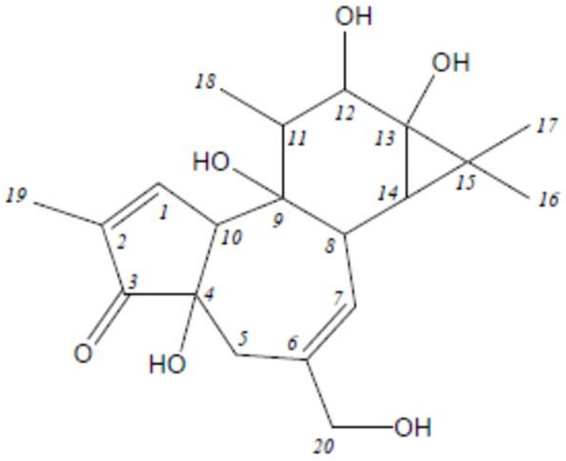
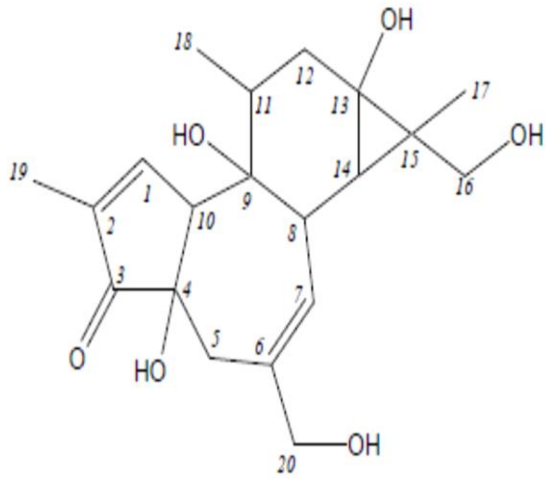
2.4 Biopesticides/Insecticides

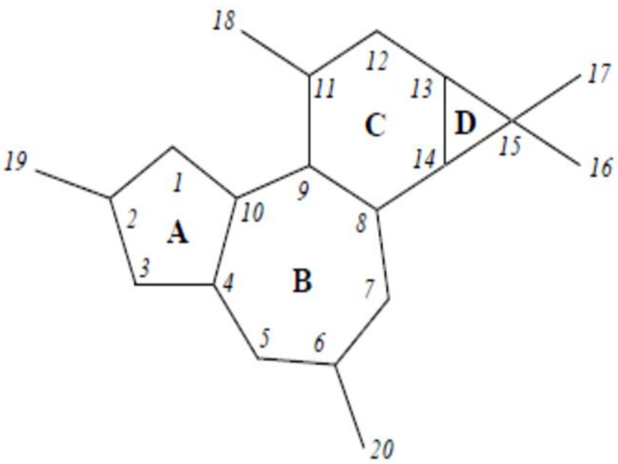
In addition to its use as a biofuel, *Jatropha* oil can also be used as a biopesticide (Habou *et al*., 2011). Several authors have tested the use of oil emulsion against insects that attack stored maize grains. Due to the environmental concern and expensive/synthetic insecticides, the demand for alternative source(s) of insect pest control has increased. Also, the pervasive used of these insecticides in granaries of small scale farmers has led to a number of problems, such as killing of non-target species, user hazards, found residues, evolution of resistance to the chemicals, high cost of the chemicals and the destruction of the balance of the ecosystem (Musa *et al*., 2011).
Jatropha curcas contain some toxins and anti-nutritive compounds which had been identified as curcin, tannins, phytates, flavonoids, saponins, vitexine, cyanide and typsin inhibitor.However, phorbol esters have been identified as the major toxic compounds in *Jatropha* (Musa *et al*., 2011; Jumat & Waleed, 2012), which depend on the types of soil and climatic conditions (Wakandigara *et al.*, 2013). The term phorbol ester is used today to describe a naturally occurring group of compounds mainly distributed in plant species of *Euphorbiaceae* family.



phorbol ester



12-deoxy-16-hydroxy phorbol



tigliane

According to Ratnadass & Wink (2012) and Wakandigara *et al.* (2013), six phorbol esters have been characterized from *Jatropha curcas* seed oil and designated as Jatropha factors C_1, C_2, C_3, epimers C_4, C_5 and C_6, with the molecular formula $C_{44}H_{54}O_8$.

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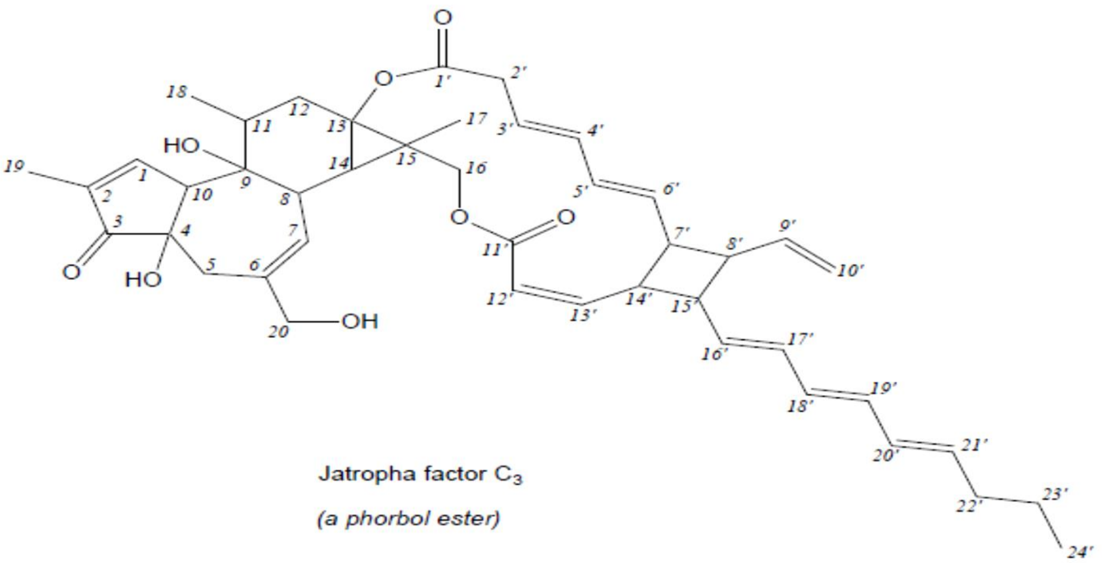
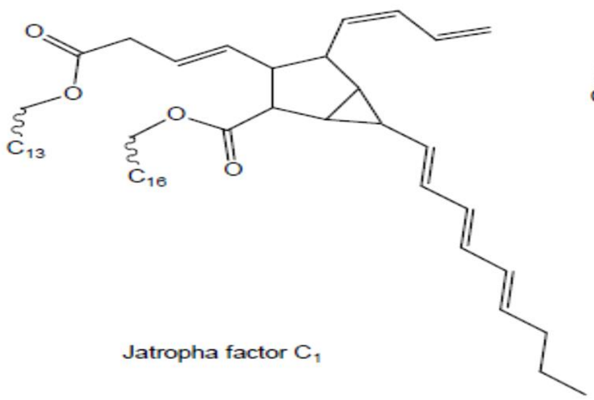
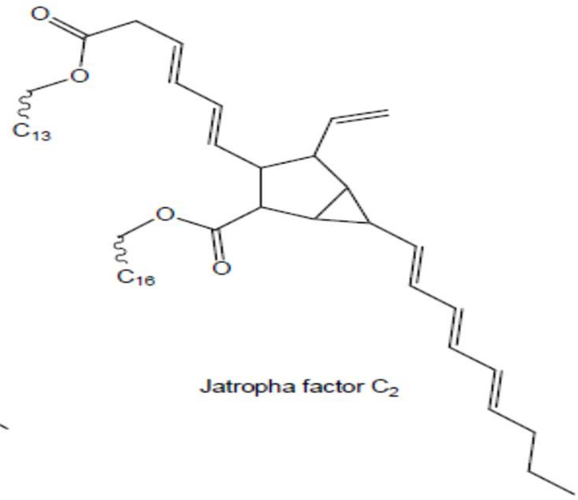


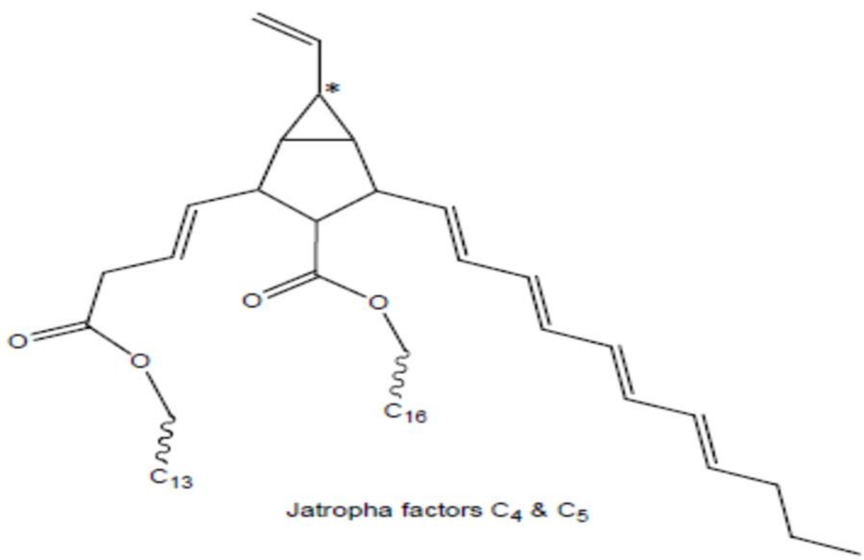
Jatropha factor C_3
(a phorbol ester)



Jatropha factor C_1



Jatropha factor C_2



Jatropha factors C_4 & C_5

(They are isomeric at C*, C_4 has S and C_5 has R configuration)

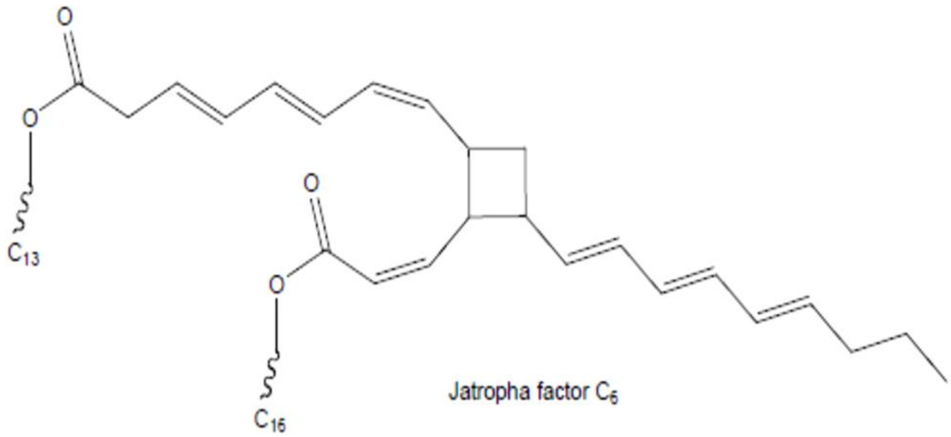


Figure 3: Phorbol esters(Adapted from Wakandigara *et al*., 2013)

Procedure for the Extraction of Phorbol esters from Jatropha Oil

The procedure for the isolation of phorbol esters by Hipal *et al.* (2009) is as described below:

- Weigh 10g of oil extracted from *Jatropha curcas* seed
- Add 250ml n-hexane to increase the volume and surface area of the oil.
- Homogenize the mixture by gentle mixing.
- Transfer the mixture to a separating funnel and add 200ml methanol dropwise to the mixture.
- Allow the mixture to settle in two layers for two hours.
- Collect the lower layer of methanol dropwise without disturbing the upper layer of hexane in a clean separate beaker.
- Repeat extractions four times for complete extraction of phorbol esters present in the oil.
- Keep the collected methanol extract in a water bath to remove the methanol from the extracted material.

It is important to note that the naturally occurring phorbol esters are unstable and susceptible to oxidation, hydrolysis, transesterification, and epimerization during isolation, procedures. Due to their oxygen sensitivity, the isolation must be conducted in oxygen-free conductions. The derivatized phorbols are then separated using high performance liquid chromatography HPLC protocols (Makkar *et al.*, 2007).

The toxicity of *Jatropha curcas* oil and seed cake (phorbol esters) have been used against maize weevil (Musa *et al.*, 2013), termite (Satyawati *et al.*,2011), aphid (*Aphis fabae*) and on the main insect pests associated with cowpeas (Habou *et al*., 2011),callosobruchus maculates (Adebowale & Adedire, 2006; Ravindra, 2010), insect pests of cotton, cowpea, maize, musk melon, okra, rice, sorghum e.t.c. (Ratnadsass & Wink, 2012), cowpea (Katoune *et al*., 2011) with promising results (high mortality) against these insects.

2.4 Other Economic and Commercial and medicinal Uses of *Jatropha Curcas*

Jatropha and other non-edible vegetable oils *(Pongamia* oil, *Madhuca* oil, *Castor*oil e.t.c.) have shown potential as a resource for biolubricant with good lubricating properties comparable to fossil lubricants (Amit & Amit, 2012). The oil is also incorporated in cosmetics and soap products, and the seed kernel meal remaining after oil extraction is rich in nutrients and used as an organic fertilizer (Makkar *et al.*, 2012). The oil extracted from Jatropha can be used as a substitute for kerosene without any further processing (Ofori-Boateng & Lee, 2011).

In many parts of the world including Nigeria, it is used as a live fence and for erosion control and shifting of sand dunes (Kumar & Sharma, 2008). *Jatropha curcas* oil has been promoted as germination prompter. The seeds of *Jatropha* contain viscous oil, which can be used for manufacture of candles. The leaves are used in traditional medicine against coughs or as antiseptic after birth, and the branches for chewing sticks (Nabil *et al.,* 2013). The bark, leaf and tender stems of *Jatropha curcas* yield a dark blue to blackish brown dye which is reported to be used for colouring cloth, fishing nets and lines. The plants and fruits hulls could be used for firewood and seed cake resulting in very high-quality charcoal that has the potential to be used in high value markets (Misra & Misra, 2010). *Jatropha curcas* plant is antibiotic and used for toothache and as blood purifier (Oduola *et al.,* 2005).

Table 6: Chemical isolated from different Parts of the Plant

Various parts	Chemical composition
Aerial parts	Organic acids (o and p – coumaric acid, p-OH-benzonic acid, protocatechuic acid, resorsilic acid, saponins and tannins
Stem bark	β-Amyrin, β-sitosterol and taraxerol
Leaves	Cyclic triterpenes stigmasterol, stigmast-5-en-3β, 7β-diol, stimast-5-en-3β, 7α-diol, cholest-5-en-3β, 7β-diol, cholest-5-en-3fl, 7α-diol, campesterol, β-sitosterol, 7-keto-β-sitosterol as well as the β-D-glucoside of β-sitosterol. Flavonoids apigenin, vitexin, isovitexin leaves also contain the dimer of a triterpene alcohol ($C_{63}H_{117}O_9$) and two flavonoidal glycosides
Latex	Curcacycline A, a cyclicoctapeptide curcain (a protease)
Seeds	Curcin,a lectin, Phorbolesters, Esterases (JEA) and Lipase (JEB)
Kernel and press cake	Phytates, saponins and trypsine inhibitor
Roots	β-Sitosterol and its β-D-glucoside, marmesin, propacin, the curculathyranes A and B and the curcusones A-D. diterpenoids jatrophol and jatropholone A and B, the coumarin tomentin, the coumarino-lignan jatrophin as well as taraxerol

Source: Kumar and Sharma (2008)

The watery sap of *Jatropha curcas* can be put onto fresh cuts and sores at the corner of the mouth, and can also be used as antidotes for venomous stings and bites. The seed oil is applied to soothe rheumatic pain (Omale*et al.*, 2011). *Jatropha* biomass has been reported as renewable materials for biocomposite fabrication (oil cake incorporated glass epoxy composites, oil cake filled styrene-butadiene rubber composites), as alternative carbonized filler polymer composite, carbon black and activated carbon, as resin and adhesive (Abdul-Khalil *et al.,* 2013).

The latex of *Jatropha* contains an alkaloid known as *"Jatrophine*" which is believed to be anti-carcinogenic. It is also used as external application for skin diseases and rheumatism and for sores on domestic livestock (Haque *et al*., 2011). The latex has antimicrobial property (Egharevba & Kunle, 2013). The medicinal properties of *Jatropha curcas* are due to the presence of certain specific substances, referred to as bioactive principles or phytochemicals which are stored in roots, leaves, stem bark, fruits and seeds.

2.5 Employment Generation

Nigeria's growing unemployment situation is alarming and it increasingly dwindles the potential of the country, especially following official figures from the Bureau of statistics that puts the figure at about 20% (about 30 million), which did not include about 40 million other Nigerian youths captured in World Bank Statistics in 2009. By implication, it means that out of the 150 million Nigerians, 50% are unemployed, or worse still, at least 71% of Nigerian youths are unemployed (Anyadike *et al*., 2012). These days, employment creation is no longer the prerogative of government, but, a joint effort between the public and private sectors. Before the discovery of oil in Nigeria, Agriculture has been the mainstay of her economy. Unemployment is one of the critical problems the country (Nigeria) is facing. The years of corruption, civil war and mismanagement have hindered economic growth of the country. Nigeria is endowed with infinite resources, but these resources have not been effectively utilized to yield maximum economic benefits. Massive unemployment is an indication of far more complex problems. It will lead to anti-social activities such as political thuggery and other social vices. Every reasonable government of the world do all it takes to create employment. *Jatropha curcas* seed can provide employment for unemployed youths in Nigeria.

For instance, Nigeria still import fossil fuel despite the facts that Nigeria is one of the largest oil producers in the world. The cost of these fossil fuels can add up to billions of dollars, and every dollar spent on energy imports is a dollar that the local economy losses. Renewable energy resources using *Jatropha curcas* oil and cake, however can be developed. Jatropha contributes to the rural poor by creating additional source of income and alleviation of countries' balance of Payment (Endalew *et al.,* 2011).

Renewable energy technologies are labour intensive. Jobs evolve directly from the manufacture, design, installation, servicing, and marketing of renewable energy products. Jobs even arise indirectly from business that supply renewable energy companies with raw materials, transportation, equipment, and professional services, such as accounting and clerical services. In turn, the wages and salaries, generated from these jobs provide additional income in the local economy. Renewable energy companies also contribute more tax revenue locally than conventional energy sources.

Furthermore, population and unemployment are like Siamese twins for developing nations. Control of unemployment can be achieved through effective population growth monitoring. Nigeria's population growth is rapidly increasing and this portends a serious danger for the nation.Thegovernment of Nigeria has a major role to play in this direction through proper counseling and sensitization of citizenry.

Conclusions and Recommendations

In today's energy demanding lifestyle, need for exploring and exploiting new sources of energy which are renewable as well as eco-friendly is a must. Nigeria has a lot of non-edible oil tree born seeds. The country is endowed with a lot of species of tree born non-edible oils seeds which can be exploited for production of biofuels to meet her energy needs. *Jatropha curcas* can be used to achieve these. *Jatropha curcas* is a versatile plant with several actual and potential uses. Development of *Jatropha* in Nigeria and the world in general gives various applications. The *Jatropha* plant can become globally competitive due to the fact that it belongs to a non-edible category and does not compete with food. Since the surge of interest in renewable energy alternative to liquid fossil fuels hits in 2004/5, the possibility of growing *Jatropha curcas* for the purpose of producing biofuels has attracted the attention of investors and policy makers worldwide.

The following conclusion and recommendations could be drawn from this present review:

- The seeds of *Jatropha* contain non-edible oil with properties that are well suited for the production of biodiesel.
- *Jatropha* end products such as seed cake, shell e.t.c has potential value. The seed cake can be used for biogas production (that can be used for cooking, heating, and lighting), as fertilizer, animal feed (if detoxified).
- *Jatropha* oil has markets other than fuel. The oil can be used for production of soap, medicine and pesticides. Other uses such as in lubrication oils, resin and adhesive among various other applications are also currently being investigated.
- The need to develop Nigeria indigenous technology to exploit her vast biofuel potentials should be emphasized.
- Aiming to diversify the energy matrix, the Federal Government of Nigeria has already established the insertion of biodiesel in the national fuel market with laws authorizing its use. Recent studies and investigations has shown that the policy is insufficient to transform the country into a biofuel economy. The country therefore, needs additional policies for the biofuel sector to succeed.
- Effort should be geared towards attracting investment from Government and private sectors, into *Jatropha* plant breeding. This would increase the likelihood of developing *Jatropha* varieties with improved and stable oil yields.
- Government of the Federal Republic of Nigeria should do more to support research on *Jatropha curcas* as a bioenergy crop and provide farmers with incentives that would boost productivity. In this manner, development of biofuel from *Jatropha curcas* would not only serve to reduce dependence on fossil fuel, but also in generation of employment opportunities, accelerated rural development and meeting the environmental obligations such as reduction of green house gases.
- Adequate information base is required on a number of scientific and processing hurdles in order to sustain the use of *Jatropha curcas* as a biobased resource especially in the area of oil processing, oil pretreatment and isolation.

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