

Alternative Sources of Petrochemicals from Readily Available Biomass and Agro-Products in Africa: A Review

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Abstract

The attention of most countries lately has been on improvement of existing goods and services. However, looking for alternative to whatever exists brings about novelty. Fossil fuel as a means of energy has been utilized for quite a long time that those who are progressive minded have begun to look for alternative sources. This is due to the fact that renewability of crude oil (current world source of energy) is uncertain. As a result the quest for bio-fuel in forms of bio-diesel, bio-gas and bio-ethanol seem to be the only hope to this impasse. Europe, Asia and America have since been at the forefront of research for alternative sources of energy. The place of Africa in this quest is unpredictable and uncertain. The surprising aspect of the whole issue is that Africa can boost of its potential to generate the resources utilizable for generation of alternative energy in form of oil seeds, agro-wastes and lignocelluloses more than other continents currently in the forefront of research into alternative energy. This review therefore, seeks to expose the resources available in African countries and how they are underutilized as well as what attempts have been made in Africa in the quest for alternative energy. It also brings to the forefront, details of basic techniques necessary in production of bio-fuel with the view that Africa as a player in bio-energy generation can do better than it is currently doing, if the leaders of the various African countries make it a priority.

Keywords: Biofuel; Bioethanol; Biodiesel; Alternative energy; Africa

Introduction

It is well accepted universally that, there is a need to look for alternative energy other than the current fossil fuel which had sustained the world population for quite a long time. Europe, South America and Asia had since been involved in research for alternative energy in the event of exhausting the current one in use. Most developed countries of the world are seriously looking for alternative forms of generating different forms of bio-energy so as not to be caught in a serious quagmire of shortage of fossil form of energy as the effect of such eventuality is best imagined. Currently, world over, biomass-derived components such as carbohydrates, lignin's, triglycerides, cellulose, hemicelluloses and sugar are being researched for possible conversion to hydrocarbon fuels. Such target fuels are meant for use in heavy-duty vehicles, jet engines, and other applications such as electricity generation that need fuels with higher energy densities than those of fossil origin ethanol or biodiesel. A possible solution to this most important challenge of the need of bio-energy availability in the world at all time could be from integration of Africa in this quest. Knowing the type of climate, soil, land mass and other eco-friendly endowment in different countries in Africa brings one to the realization that it also has a stake in providing solution to this problem. Amigun et al. [1] cited Africa as the second largest continent after Asia making up only 10% of the world's population, equivalent to about 80% of India's population. Presently, biofuel, biogas and bio ethanol are considered as the most promising alternatives in energy generation that can compete with the fossil fuel [2-4]. Soumonni, and Cozzens [5] stated that the development of biofuels can be divided into two main processes. First, is the production of the biofuel (crop and non-crop) sources and secondly, they have the end-use technologies which must be compatible with the fuels. Petrochemical potential crops are of three main types: sugar, sugar beet or maize etc (1st generation biofuel sources) for bio-ethanol; rapeseed, sunflower, oil palm or soy oil (1st generation biofuel sources) for biodiesel; wood chips or crop wastes (2nd generation biofuel sources) for cellulosic biomass ethanol and both biodiesel and bioethanol from microbial sources such as microalgae, diatoms, fungi

and other microbial sources (3rd generation biofuel sources). Large scale bio-fuels projects are becoming widespread in Africa with the twin intention of providing energy security and exporting biofuels for economic growth [5]. Feedstocks are found in abundance in Africa either as edible or non-edible. Main edible oil seeds found in Africa are soybean, groundnut, palm kernel and coconut oil, while the non-edible ones that are most commonly are *Jatropha curcas* (*Jatropha curcas* L.) and Neem (*Azadirachta indica*).

Sources of Biodiesel Generating Plants in Africa

As long as there are plants (crops, trees, shrubs and grasses) in a place, such a place has potential for generation of alternative energy. Bio-fuel generating biomass abounds in Africa. The list is endless starting from the already acceptable oil plants to the much contested lignocelluloses materials found in all African environments. As shown in Table 1 below are well known seed oil plants which offers huge possibilities of being converted into biodiesel. This review will look into the origin, availability, oil yield capabilities of these plants as well as limitation which affect their current usage for biodiesel. What need to be done to sustain their use for possible production of biodiesel will also be addressed.

Detailed evaluation of some oil producing crops in this review will help in understanding the impact these crops may have if carefully

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Oil producing Plant/ Crop	Yield (Lb Oil /Acre)
Palm	4585
Coconut	2072
Sunflower	734
Soybean	344
Cottonseed	250
Jatropha	1458
Castor bean	1089
Rubber seed	199

Table 1: Different edible and non edible oil producing crops and their yield [6].

evaluated and practically applied in the production of alternative sources of energy.

Jatropha curcas

In tropical countries, *Jatropha curcas* seed oil is being promoted for biodiesel production and the technology has been optimized [6,7]. It was found that the shell could be used for combustion, hull/husk for gasification, and cake for production of biogas, spent slurry as manure, oil and biodiesel (made from *Jatropha* oil) for running CI engines. The kernels of *Jatropha curcas* have about 50% oil [8]. The oil recovery in mechanical expeller was about 85%, while more than 95% recovery of oil could be achieved when extracted by solvent method [8]. The biodiesel from *Jatropha curcas* oil has a great potential due to its comparable properties to diesel, such as calorific value and cetane number [7].

According to Abdulkareem et al. [8], *Jatropha curcas* is native to Mesoamerica but has been distributed worldwide since the XVI century by Spaniards and Portuguese to their tropical and subtropical colonies in Africa and Asia. In India and other countries of the Far East, villagers used *Jatropha curcas* as a hedge crop, and the extracted seed oil to make soap or fuel for lamps. *Jatropha curcas* is mostly found in northern parts of Nigeria e.g. Sokoto, Zamfara, Kebbi, Kastina Minna etc. [9]. Here they are used as hedge for fencing pasture lands, combating desertification and field demarcation. Pilot scale of mass cultivation of the plant is seen in these parts of Northern Nigeria. Ghana, South Africa and Egypt are also involved in massive propagation of this wonderful plant as at present with the major goal of using the seed for biodiesel generation as a supplement and possibly a replacement for fossil biodiesel. *Jatropha* is a drought resistance tree that can be grown in areas where rainfall is as low as 500-600 mm [8].

Jatropha grow in soils that are quite infertile. It is usually found at lower elevations (below 500 m) [10]. Where rainfall is high above 1000 mm, it does better in hot rather than temperate climate [8]. These are qualities that make it a great potential for biodiesel generation in Africa. One of the advantages of using *Jatropha* for biodiesel production is the fact that it is non edible. According to [11], oil from the *Jatropha* fruit shows most promise. The fruit is poisonous, so it is not affected by the "food-or-fuel" tug of war; and it grows well on arid soils which mean it does not need felling of forests. It is very resilient and needs less fertilizer and it can be developed into plantations like any oilseed crop. Among the two common non edible oils in Nigeria, *Jatropha curcas* plants are usually found economically un-useful and invaluable [12]. These plants are mostly used as fences for houses and are present in abundant quantity in abandoned lands while the usefulness of neem plants is felt across the nation. *Jatropha curcas* is drought-resistant oil bearing multipurpose shrub/small tree, belonging to the family of *Euphorbiaceae* [13]. It originates from Central America and is widely grown in Mexico, China, north-east Thailand, India, Nepal, Brazil, Ghana, Mali, Bukina Faso, Zimbabwe, Nigeria, Malawi, Zambia and

some other countries [13]. The *Jatropha curcas* plant, which can easily be propagated by cutting, is widely planted as a hedge to protect fields, as it is not browsed by cattle or other animals. It is well adapted to arid and semi-arid conditions and often used for prevention of soil erosion [14]. 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 as reported by Augustus et al. [15]. It has a life span of 50 years, *Jatropha curcas* can tolerate high temperatures and grows very well under low fertility and moisture conditions by Juan et al. [15]. It can survive in poor stony soils [16]. Seeds of *Jatropha curcas* resemble castor seeds in shape, but are smaller and brown. Due to leaf-shedding activity, *Jatropha* plant becomes highly adaptable in harsh environment because decomposition of the shed leaves would provide nutrients for the plant and reduces water loss during dry season. Thus, it is well adapted to various types of soil, including soils that are poor in nutrition such as sandy, saline and stony soils [17]. *Jatropha* cultivation in wastelands would help the soil to regain its nutrients and will be able to assist in carbon restoration and sequestration [18].

Castor oil plant

Castor (*Ricinus communis*) is indigenous to the southeastern Mediterranean Basin, Eastern Africa, and India, but is widespread throughout tropical regions (and widely grown elsewhere as an ornamental plant) [19]. The castor oil plant (*Ricinus communis*) is a species of flowering plant of the *Euphorbiaceae* in the spurge family. It is widely grown as a commercial crop in Ethiopia for its oil, which is a medicinal commodity [20]. The leaves are glossy, 15–45 centimeters (5.9 – 17.7 inches) long, long-stalked, alternate and palmate with 5-12 deep lobes with segments coarsely toothed. The leaves of some varieties are green practically from the start, whereas in others a pigment masks the green colour of all the chlorophyll-bearing parts, leaves, stems and young fruit, so that they remain a dramatic purple-to-reddish-brown throughout the life of the plant. The stems (and the spherical, spiny seed capsules) also vary in pigmentation. The fruit capsules of some varieties are more prominent than the flowers.

The green capsule dries and splits into three sections, forcibly ejecting seeds. The fruit, greenish (to reddish-purple) capsule with spikes, containing large oval, shiny, bean-like, highly poisonous seeds with variable brownish mottling. In south eastern Nigeria, the boiled and fermented seeds are used for production of local seasoning (*Ogiri*) with a high pungent aroma used in cocoyam and bitter leaf soap culinary.

According to Chakrabarti and Ahmad [20], castor oil is a colourless to very pale yellow liquid with mild or no odour or taste. Its boiling point is 313°C (595°F) and has a density of 961 kg/m³. It is a triglyceride in which approximately 90% of fatty acid chains are ricinoleic acid. Oleic and linoleic acids are the other significant components. Ricinoleic acid, a monounsaturated, 18- carbon fatty acid, is unusual in that it has a hydroxyl functional group on the twelfth carbon. This functional group causes ricinoleic acid (and castor oil) to be unusually polar. It is the hydroxyl group which makes castor oil and ricinoleic acid valuable as chemical feedstocks. Like any other vegetable oil it can be converted to bio diesel as described by Schuchardt et al. [21]. This feedstock is found in all countries in Africa. There is at present no massive cultivation except in Ethiopia. With the adaptation of this crop in African climate and soil it is a potential bio-diesel feedstock. Due to the low need as at present being a good source of oil and protein, it is only moderately cultivated as a subsistent crop in Africa to meet only the nutritional requirement of sub-saharan tropical communities. Perhaps massive cultivation of castor plant with the aim of using the seeds for biodiesel

generation should be strongly considered and encouraged as an alternative energy in Africa considering that this plant grows well and seeds are harvested for up to five years [22].

Oil palm (*Eleaieis guineensis*)

Oil palm (*Eleaieis guineensis*) is a tree crop found in rainforest regions of the tropic. It is primarily cultivated for its vegetable oil source for use in domestic culinary and local soap production. Table 2 though not exhaustive, illustrates the range of uses to which palm oil is subjected. Here two categorizations are made; food and nonfood usages.

It thrives well in deep soil, average high temperature and largely moisture containing soil. Oil palm originated from West Africa especially the Niger Delta areas of Nigeria and Liberia. According to Verhey [23], oil palms are sporadically encountered up to St. Louis in Senegal and the Upper Niger valley near Bamako. Minor palm groves are observed around Dakar and in the Gambia, but their production is too low to justify the establishment of commercial oil mills. The real palm belt in Africa runs through the Southern latitude of Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, and Cameroon and into the equatorial regions of Equatorial Guinea and the Congo. The Northern limit of this belt varies with the isohyets of 1200 mm rain per year and with the topography of 400m altitude. There is a small area surrounding Accra where due to low rainfall (less than 650 mm/year), oil palm estates are absent.

The extension of oil palm in East Africa is irregular. Most of East and South-East Africa is too dry and, therefore, the crop appears only at altitudes below 1,000 m near lakes or watercourses with reasonable rainfall [23]. Its present on the eastern coast of Madagascar is due to a local micro-climate, though in this area the crop can be affected by tonado [23]. Palm oil is the main vegetable oil produced in Nigeria. In the 60's, Nigeria was the world leader producer and exporter of palm oil [24]. As regards to palm oil production in Africa, however, Nigeria's production is estimated at 55% of the African output [24]. Nigeria and indeed Africa has a potential to increase palm oil production but has technology limitation due to inability to apply improved processing methods and better marketing. As shown in Figure 1, in 2006 Nigeria has palm oil plantations in over 1 million hectares of land mass [25,26].

However, the interest of this work is about utilization of oil palm as source of alternative energy generation. In Table 2, the last among the list of non-food uses of oil palm is biodiesel. Thus there is no doubt that palm oil could be refined to produce biodiesel. The issue is how has African countries really considered integrating it into their national plan for energy generation? The current situation is that there is shortage of palm oil for domestic consumption in food usage. There are also other competing nonfood uses that make the availability a

challenge. However, increased production on commercial scale for any purpose such as biodiesel is possible if governments of various African countries deem it a priority in alternative energy generation in their respective countries.

Basiron [27] stated that the high petroleum prices in 2005 and 2006 led to many countries considering biodiesel production from renewable resources. This new application opened up a potentially large market outlet for palm oil as well as other major oils and fats. The first decade of the 21st century can therefore be regarded as the period of creating additional demand from bio-fuel, which in turn stimulated supply expansion in all producing countries.

Basiron [27] further stated that oil palm, being eco-friendly by its very nature, is a highly productive crop with an output-to-input energy ratio of 9:1 compared to 3:1 for other oilseed crops such as soybean or rapeseed. This is manifested by the tenfold higher yield of oil. Superior productivity is also reflected in high photosynthetic rates resulting in oxygen emission and carbon dioxide absorption rates that are ten times more effective than those observed for soybean. Oil palm cultivation also uses comparatively less land to supply oils and fats for food and non-food uses, including biodiesel, for the world. Therefore, it is important in Africa to look serious at oil palm cultivation since the tropic environment seriously accommodates the growth and productivity of palm trees. The use of systematic planting method to optimize more number of palm trees per hectare for the purpose of biodiesel production should be encouraged in Nigeria, Ghana, Ivory Coast, Cameroon and the entire West African region. North African countries like Egypt, Tunisia, and Sudan might also start research on the same purpose with palm tree plantation as well as other types of oil plants, South and East African countries should not be left out in this noble quest.

Palm oil industry in Nigeria: There is a consensus that the oil palm (*Eleaieis guineensis*) is a native of West Africa [28]. IPPA [28] reports stated that palm trees are found predominantly in southern Nigeria especially in the wet rain forests and savanna belt. It also exists in the wet parts of North central Nigeria, in areas like Southern Kaduna, Kogi, Kwara, Benue, Niger, Plateau, Taraba and Nasarawa States as well as the Federal Capital Territory (FCT).

There are three categories of palm plantation;

- i) Small holding
- ii) Medium size plantation
- iii) Large scale (estate) plantation.

Small-holder farmers control palm cultivation in Nigeria. Smallholding farms cover a range of 1-5 hectares and are sometimes characterized by mixed cropping obviously to maximize the usage of the land. A large chunk of oil palm exists in the wild or semi-wild state, when this is added to those that were cultivated by smallholders, it shows that the small-holding control over 80% of the Nigeria palm oil production [29]. Historically, Nigeria is largely an agrarian society [28]. Also IPPA [28] agreed that agriculture was the mainstay of the economy during the pre-colonial and the colonial period. Despite lack of modern farm implements which undermined the potential for large-scale production, Nigeria emerged in the first decade of her independence as a leading exporter of many major agricultural commodities. Nigeria was a leading exporter of palm kernel, and largest producer and exporter of palm oil. During that time, smallholder farmers collectively produced 90 percent of the food needs [30] and 70 percent of Nigeria's export earnings - a dominant share of the country's GDP [31] (Figure 2).

Food uses	Non-Food uses
Cooking Oil	Cosmetics and Personal
Deep Frying Oils	Soaps
Margarines and Spreads	Candles
Bakery Fats	Pharmaceuticals
Cocoa butter alternative fats	Lubricants and Grease
Confectionary Fats	Surfactants
Ice cream fats	Industrial Chemicals
Infant nutrition fats	Agrochemicals
Other food applications	Coatings, paints and lacquers, Electronics, Leather, Biodiesel

Table 2: Food and non-food uses of palm oil products [22].



Figure 2: Small-holder palm oil production provides many job opportunities. (Mbongo, Littoral, Cameroon) [26].

IPPA [28] reports reasoned that Nigeria has untapped potential for massive agricultural production. However, the critical issue is that policy makers should rescue agricultural production in areas where the potentials for massive production exist. Taking the example of palm oil which was once a major source of foreign exchange for Nigeria, its importance in world economy is still sacrosanct. In today's world, palm oil remains one of the veritable means of reducing the uncertainties in the oil and gas sector. The current reality is that Nigeria relies on oil and gas as the main source of government's revenue. In spite of oil exports accounting for over 80 percent of its income, it is contributing only 5.5 percent to the gross domestic product (GDP) (<http://www.nigerianstat.gov.ng/>). This fact questions the utilization of resources and also exposes how vulnerable the country is to the vagaries and fluctuations in the price of oil exports [28].

Revitalization of the agro industry in Nigeria could increase all

the oil crop production output and utilization in biodiesel sector of the national economy. Moreover, because every part of palm tree is useful many other low cost and low technology economic activities will emerge around the oil and non-oil uses of oil palm, biodiesel inclusive, and thereby creating employment for the country's workforce.

In Nigeria many of the local owners of palm oil plantations as well as those who are involved in palm oil business do not experience any environmental harm as a result of palm oil production [28]. The palm oil industry does not hamper forest biodiversity in Nigeria. Studies have shown that palm oil produces two to three times more oil from the same amount of land as the other major sources of vegetable oil – rapeseed and soybean [32].

Ghana's palm oil industry: Like most other countries in Africa, Ghana has a long history of palm oil production. It was its primary export in later part of the 19th century and the early part of the 20th

century [33]. Like other countries in the region, Ghana has failed to take palm oil production beyond mere potential. This is due to the use of traditional methods of production coupled with the low quality of palm oil produced which could not make Ghana to meet up with the rising global and domestic demand.

IPPA [28] sources had it that land is relatively abundant in Ghana but access is curtailed by cultural practices. Out of a total land area of 238,537 km, 64 percent of which is suitable for agricultural production, only 39 percent is under cultivation. This tends to show that if the palm oil sector is well exploited and modern production technology is introduced, the sector has the potential of lifting many out of poverty especially if bio-fuel is also considered in cultivation and refining of palm oil products (palm oil and palm kernel oil).

Palm kernel oil: This oil is gotten directly from the nut embedded within the kernel of the palm oil fruit. The method of obtaining Palm Kernel Oil (PKO) involves: cracking the kernel, separating out the Nuts, and extracting the oil. The history of palm kernel is as old as the palm tree. The uses of the kernels are:

Industrial: Countless house-hold materials are produced from palm kernel oil. These products range from washing powder, candle, printing ink, grease, ointments (Pharmaceuticals), glues, waxes and candles, gloss, vanishes and polishes etc.

Cosmetics: Palm kernel oil is the basic ingredient used by small, medium and even large cosmetic industries in their production due to its cost effectiveness. The range of products made from (PKO) include: Pomades, Detergents, Soaps, Body Creams, and Hair Creams.

Food and bakery: Confectionaries and domestic cooking find Palm Kernel Oil as a great delight in their range of baking and cooking recipe. Some of the uses involve: flour chips, bread, snack, biscuit baking. Hydrogenated palm kernel oil becomes semi-solid at room temperature, thus suitable for making margarine, sweet and chocolate production. Domestically, it is used in cooking and frying different food such as yam, plantain, stew etc. In Nigeria, it is the most affordable vegetable oil.

Bio-fuel and biodiesel: Locally PKO is used in constructed lamps to light up homes during the night in Africans communities where electricity is either absent or is in short supply. Of recent and of major interest in this work is its application as biodiesel substitute to those from fossil sources due to its renewability and eco-friendly potentials.

Local African palm kernel extraction: According to Agbogun [34], the entire process of PKO extraction is manual. De-hulling is done by cracking the kernel with stones. Each kernel is placed on a stone while a smaller stone is used to hit it against the bigger stone. Once the Kernel is cracked, the Nut is picked up into a Bowl, the Stone is cleaned, and another Kernel is introduced for cracking. Next the kernel is place inside a pot, covered, and heated with fire made from fire wood. Heating is followed by a dense fume with characteristic aroma that usually spread to very far places. The heat allows the oil to drain out of the nuts leaving a black fragile charcoal-like Mass. The dense black oil is separated and stored in small containers like bottles. Palm Kernel Oil made in this way is used by local African people for pomade and medicine.

Mechanical extraction: Agbogun [34], further explained that mechanical extraction could be used for small-scale or large-scale extraction of Palm Kernel Oil. Palm Kernels are pre-treated by Magnetic Separators that removed metallic debris that might destroy the device. Then the kernels are sieved to remove sands, stones and other impurities

before cracking with inbuilt swinging hammers. The nuts are separated from the shells after cracking and prepared by heating before squeezing with a Screw-Press (Ram-press). The nuts are screwed through a metallic path (with pores) that decreases in diameter to the exit so that the oil is forced out of the side while the cake is collected at the tip of the screw. Finally, PKO obtained via mechanical means are usually filled with impurities that must be removed by further processing. This is used when Palm kernel oil is needed in commercial quantities such as in industries. Thus, this process could serve the purpose of extraction of the oil should it be needed for production of biodiesel.

Neem

The neem known as *Azadirachta indica* is a tall tree measuring up to 30 meters. This ever – green tree which sometimes spreads like oak trees bears masses of honey – scented white flowers that develop into small fruit clusters of small bunch. This resilient plant which can survive for up to 200 to 300 years has been reported by most researchers to have originated in India and Burma. It usually starts fruiting after 3 – 5 years and seldom leafless (reason for referring to it as evergreen). It is a choice of plant for provision of shade in the tropics. It is a highly valued plant by Indians and native Africans due to its medicinal properties and its ability to resist draught. According to Tinghui et al. [35] Indian immigrants introduced neem to Mauritius and may also have taken it to continental Africa. It is now widely cultivated in Mauritania, Senegal, The Gambia, Guinea, Ivory Coast, Ghana, Burkina Faso, Mali, Benin, Niger, Nigeria, Togo, Cameroon, Chad, Ethiopia, Sudan, Somalia, Kenya, Tanzania, and Mozambique. Because of tree planting programs of the Forestry Department and of the local people, Senegal has more neem trees than any other African country. Senegal is thus the African leader currently in neem cultivation and usage. The tree dominates towns and villages all over the country [35].

Neem is common in Nigeria, found scattered in towns and villages, all over the country. The government and people of Nigeria have not yet seen the need to cultivate neem in plantation even though there is great awareness of its properties both medicinal and otherwise. Most families have between one to five neem trees either serving as shade or for medicinal (its leaves are boiled and aqueous extracts drank as anti-malarial drug) uses. Nwokeabia [36] reiterated that neem forms about 90% of trees in the forestry plantation established in 12 states in Nigeria within the savanna zone under an afforestation programme. In Chad, neem constitutes about 17% of the tree cover [37]. Massive Neem cultivation has been used to halt the encroachment of Sahara desert into Mauritania from Somalia.

The neem seed oil is known to contain anti-nutrient compounds making it most unsuitable for consumption as food by both man and livestock. According to Karkar [38]; Raman and Santhanagopalan [39], the presence of Tignic acid is believed to be responsible for the distinctive odour of neem seed and the sulphur containing compounds such as nimbin, nimbidin and nimboesterol, though having insecticidal properties, have been established as being responsible for the bitter taste. These properties no doubt make the neem seed oil quite undesirable for consumption except for industrial purposes. Pharmaceutical, cosmetics and textile industries worldwide have found great uses for neem oil [40]. Neem oil and powdered leaves have found great uses in various cosmetic preparations such as face creams, nail polish, shampoos, nail oils and hair conditioners [40]. Neem oils are also used in special soap preparations and toothpastes, while neem cake (the by-product of neem oil industry) is used in formulation of fertilizer, natural pesticide and livestock feeds. These industrial qualities have shown it to be a good candidate for the production of high quality biodiesel.



Figure 3: Groundnut (*Arachis hypogaea*) [43].

Africans can benefit immensely in this by exploiting the durability of this plant as well as the availability of the seed all year round in the bid for alternative energy. The only challenge for countries like Nigeria, Ghana, South Africa, Kenya and Egypt that are already interested in biofuel generation is massive propagation of neem plant in commercial plantation scale for the purpose of biodiesel production from the seed oil.

Groundnuts

Peanut or groundnut (*Arachis hypogaea* L.), originated in South America (Bolivia and adjoining countries) but currently produced throughout the tropical and warm temperate regions of the world. During the sixteenth century, due to European expansion it was taken to Africa, Asia, the Pacific Islands and Europe where it was greatly cultivated. Being mainly native to warmer climates, groundnuts frequently provide food for humans or livestock, and in the absence of meat, form a valuable dietary protein component [41] (Figure 3).

The essential component of the groundnut is its oil which has pleasant aroma and very edible in its naturally extracted form. In Nigeria, the byproduct of the processed oil is formed into groundnut cake known as *kulikuli*, a notable snack in northern Nigeria and quite popular all over Nigeria. Groundnut oil refining plants dry these by product after oil extraction and market them as pellets to those who need them for animal feed compounding. In the 60s, Nigeria being agrarian before the discovery of crude oil, was the world leading producer of groundnut. Cities like Kano, Kaduna, Katsina, Gongola and Sokoto were famous due to the stacking of bags of harvested groundnuts into pyramid mounds for exportation, which earned the country great foreign exchange. Elsewhere the groundnut oil is processed into margarine, pharmaceuticals, soaps, paint and cosmetics. Jimoh et al. [42] stated that in Northern Nigeria, women usually do extraction of groundnut oil locally. The women extract the oil to generate substantial income to support their domestic needs with little or no consideration given to groundnut species or the physicochemical properties of the oil. Most women rely on availability rather than quality. Groundnut is mainly grown in the Northern part of Nigeria and the oil is readily available in all parts of Nigeria in large quantities.

According to DAFF [43], seeds yield non-drying, edible oil, used in cooking, margarines, salads, canning, and deep-frying; the oil content of the groundnut kernels is between 45% and 55%. Groundnut oil contains high levels of energy, fat soluble vitamins (A, D, E and K) and essential fatty acids. Seeds can be eaten raw or boiled and roasted for immediate consumption. They can be chopped into confectioneries, or ground into peanut butter. Groundnuts are also used for sweets (brittle). Young pods may be consumed as vegetable. Young leaves and tips are suitable as a cooked green vegetable. Other products from groundnuts include ice cream, massage oil and peanut milk. DAFF [43]

further gave the industrial uses of groundnut to include: raw material for manufacturing pharmaceuticals, soaps, hair creams, cosmetics, dyes, paints, lubricants; emulsions for insect control and fuel for diesel engines. It can also be used to produce a fluid diet used to strengthen patients physically and sharpen their appetites before and after operations. The hulls are used for furfural and as filler for fertilizers.

Traditionally in Africa, oil is extracted from groundnuts by roasting and crushing to as fine as possible (i.e. first by pounding, followed by crushing between stones or a stone and an iron bar). Afterward, the crushed mass is mixed with water, and the oil is obtained by cooking the mixture, causing the oil to float. The oil is finally skimmed off and dried by heating [44]. Currently, milling machines are used in crushing the roasted groundnut to viscous pastes before being boiled to obtain the groundnut oil.

According to EOLSS [45] report, in Africa, groundnut is grown mainly in Nigeria, Senegal, Chad, Ghana, Congo and Niger. In 2007, the total harvested area in Africa was 9.04 million ha with a total production of 8.7 million Mt. The average productivity in this region is 964 kg/ha, which is poor when compared to US and other developed countries where it is close to 3500 kg/ha. Average productivity is 1720 kg/ha in Nigeria, 500 kg/ha in Sudan and close to 700 kg/ha in Senegal. For a long time groundnut was the main export product of Senegal and the Gambia.

The level of cultivation of groundnut in Africa is inadequate considering the fact that the African climate and soil are ideal for its propagation. The African countries listed for mass production only do so for domestic consumption and little exportation. Most of the developed countries that import groundnut do so not for domestic consumption but for industrial application of the processed oil. Thus, until Africa begin to see the need of commercializing products of groundnut source it will not see the need to propagate this wonderful oil crop in commercial plantation scale. Perhaps, biodiesel production from groundnut oil will give the impetus for more cultivation of groundnut in Africa as this will not only help in creating employment but will also help in the industrialization of the continent. According to Jimoh et al. [42] commercial availability of biodiesel is therefore influence by the feedstock availability, which can be achieved in Nigeria through groundnut oil with production rate of 200 000 metric tonne per year. It has been reported that Nigeria possesses land area of 923,768 km² arable land constituting about 56% and vegetation ranging from the Sahel savanna in the extreme North to swamp forest in the south [46]. Therefore, most parts of Nigeria are suitable for biofuel crop cultivation. Although an edible oil, its use as a potential feedstock for biodiesel production may not likely compete with other crops grown for food and commercial cooking oil products. Nigerian is ranked 3rd in the world for the production of groundnut oil [47].

Jimoh et al. [42] explained that the reduction in annual production of groundnut oil between the year 1976 and 1994 can be attributed to the diversion of Nigerian economy from agricultural oil exploitation economy due to discovery of oil in Nigeria. The recent interest (from 1999 till date) in the production of groundnut can be attributed to the Nigerian government commitment to the production of alternative renewable energy sources. Biodiesel has been identified as the alternative energy in the country with groundnut oil as the perfect feedstock for its production in as much as it does not affect the oil supply for consumption purpose.

Soybean (*Glycine max* (L.))

Soybean (*Glycine max* (L.)) originated from Eastern Asia, probably in north and central China [48]. It is believed to have originated from the orient [49]. Soybean is a leguminous vegetable of the pea family that grows in tropical, subtropical, and temperate climates. Soybean was domesticated in the 11th century BC around northeast of China. It is believed that it might have been introduced to Africa in the 19th century by Chinese traders along the east coast of Africa (www.soybeanIITA.htm). Cultivated varieties were introduced to Korea and later to Japan 2000 years ago [48].

A brief history of adaptation of soybean in Africa according to Chianu et al. [50] started in 1908 when there was a dramatic increase of interest in growing soybeans in Africa, as Europe for the first time began to import large quantities of soybeans from Manchuria in response to severe shortages and high prices of oil in Europe. European nations turned to their African colonies as potential areas for soybean cultivation. English colonies were most actively involved. Very little was done to introduce soybeans to the many French colonies. By 1908 soybeans were being grown on a small scale in Nigeria and in the Belgian Congo. Extensive investigations were made on all British Governmental Experiment Farms in Africa and by 1910, it was found that, given the present demand and prices, the colonies could compete very successfully with imported Manchurian soybeans. The most vigorous and extensive cultivation work was done in South Africa, and a number of detailed reports were published on this work starting in 1910. During the 1920s soybeans were first introduced to Egypt, Zimbabwe (then Rhodesia), and Rwanda. In 1938 they were introduced to Uganda. The earliest known report of soyfoods in Africa dates from the early 1930s, when Catholic missionaries organized soymilk production in Zaire (at that time the Belgian Congo). The earliest known commercial soyfood in Africa was soy flour introduced in South Africa in 1937 by a well-known milling company and used by a number of gold mines on the Rand to fortify the diets of mine workers. There was little activity or interest in soybeans and soyfoods during World War II, but shortly thereafter a brief attempt was made to introduce tempeh to Rhodesia. In 1950 soybeans were first grown in Ethiopia. During the 1960s there was a gradual increase of interest in soybeans and soyfoods throughout Africa. In 1962 Africa's second commercial soyfood, ProNutro, a soy-fortified blend, was introduced in South Africa. During the 1960s, according to the FAO Production Yearbook, total African soybean production increased from about 50,000 tonnes (metric tons) in 1960 to 75,000 tonnes in 1969, for a growth of 50% in ten years. The great majority (80-90%) of these soybeans were grown in Nigeria. From the early 1960s until 1976, soybean production in Africa had increased slowly but steadily, but in 1977 takeoff began, fueled by large increases in production in Egypt and Zimbabwe. By 1981 the African total had jumped to 265,000 tonnes; the four largest producers were Egypt (136,000 tonnes), Zimbabwe (97,000), Nigeria (est. 80,000), and South Africa (26,000).

Production of soybean in Africa: Soybean is cultivated in sub-Saharan Africa to a very limited extent [48]. During the last decade or so, the African continent accounted for 0.4% to 0.6% of the world's total production of soybean, the main producers being Nigeria (437,000 MT global production), South Africa (221,000 MT), Uganda (166,000 MT), Zimbabwe (83 000 MT), and Rwanda [51]. Overall, about 19 African countries appear in the world soybean production statistics [51]. According to FAO [51] these countries and the proportion (%) of African soybean production that each accounts for are: Nigeria (48.9%), Uganda (16.8%), South Africa (14.9%), Zimbabwe (8.4%), Ethiopia (2.7%), Rwanda (2.0%), Egypt (1.7%), and DRC (1.4%). Others are: Cameroon (0.8%), Benin (0.7%), Cote d'Ivoire (0.3%), Liberia (0.3%), Burkina Faso (0.3%), Zambia (0.2%), Gabon (0.2%), Tanzania (0.2%), Morocco (0.1%), Burundi (0.0%), and Madagascar (0.0%). With this minimal share of world production, the sub-Saharan African (SSA) region is a net importer of edible oil and protein cake and protein meal mainly for the livestock industry.

Soybean consists of more than 36% protein, 30% carbohydrates, and excellent amounts of dietary fiber, vitamins, and minerals. It also consists of 20% oil, which makes it the most important crop for producing edible oil (www.soybeanIITA.htm).

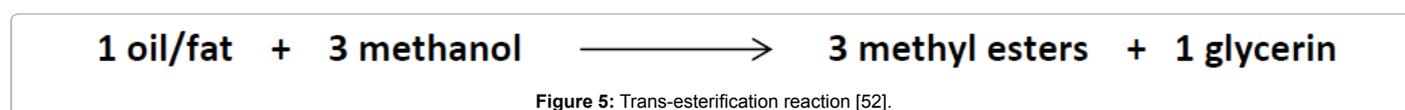
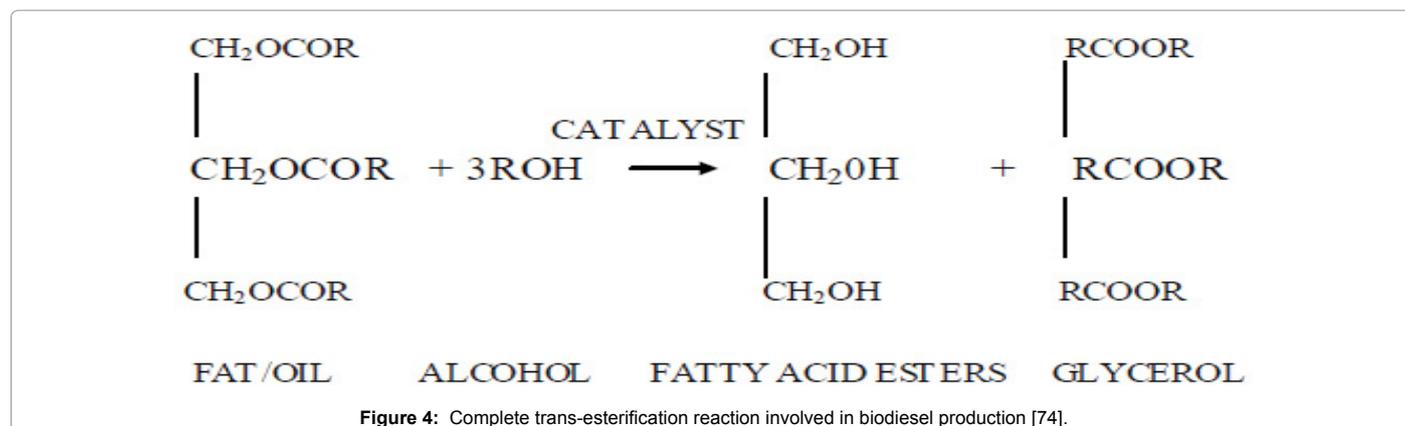
FAO [51] stated that nearly 95 million hectares of soybeans were harvested worldwide in 2007, with 19 million in Asia, 3.5 million in the USA, and 1.2 million in Africa. Africa exports about 20,000 tons annually. Commercial soybean production on large farms takes place in Zambia, Zimbabwe and South Africa. However, it is mostly cultivated by small-scale farmers in other parts of Africa where it is planted as a minor food crop among sorghum, maize, or cassava. Nigeria is the largest producer of soybean in Sub-Saharan Africa (SSA), followed by South Africa. Since soybean contains 20% of oil in its seeds and this oil is edible with high quality such that it could be refined into good bio-diesel, African countries should therefore greatly consider it as a potential source of biodiesel. Currently, the high demand of soybean for its nutritional purpose both from humans and domestic animal possess a great impediment to its consideration for biodiesel production more so now that most Africans are deficient in great quality protein source from both plant and animal source due to its cost making it unaffordable for majority of the populace. These impediments notwithstanding, governmental demonstration projects and commercial firms may seriously consider its production for the purpose of bio-diesel generation due to the fact that it could be propagated 3 times annually especially by making use of irrigation farming methods.

Biodiesel

In addition to the various oil seed plants elaborated above that are of African origin or foreign but thriving well in sub Saharan Africa, other sources to be exploited include: genetically modified Seed oil, Animal fats (shark, whale, buffalo, beef and pork tallow), and oil from microbial source (microalgae, planktons and other bacterial components) as well as waste cooking oil. All these abound in and around Africa.

Biodiesel production

The commercial method used for biodiesel production is transesterification (also called alcoholysis). The transesterification process consists of the reaction of oils or fats (triglycerides between 15 and 23 carbon atoms, the most common being 18) with an alcohol of low molecular weight (usually ethanol or methanol) in the presence of alkaline catalyst (usually NaOH or KOH) to produce esters and glycerin. Normally, the reaction takes place at atmospheric pressure



and temperature of 65°C. Constant agitation, during an interval of time between one to twelve hours using a rotor or shakers gives a good yield. The transesterification consists of three consecutive and reversible reactions as shown in Figure 4.

The stoichiometric ratio for the transesterification reaction is three moles of alcohol and one mole of triglyceride (Figure 5). An extra amount of alcohol is added in order to move the reaction to the methyl esters formation. Glycerin is also formed in the reaction. The by-product, glycerin, has an economical value. The glycerin can be used in manufacturing of hand cream, soap, toothpastes, and lube [52] all products hitherto manufactured from petrochemicals.

Several other side reaction occurs which if uncontrolled hampers conversion, product yield and quality [53]. Alejandro [52] explained that saponification and free fatty acid neutralization are undesirable side-reactions. These side reactions consume the catalyst. As a result, the yield of biodiesel decreases. The purification and separation steps become more complicated. The saponification takes place only in the presence of hydroxide group (OH). It occurs when the catalyst is potassium or sodium hydroxide. The soap formation can be avoided by using an acid catalyst. Thus, the presence of water or free fatty acid favors the formation of soap. For this reason the oils and alcohols have to be essentially anhydrides. The water can be removed by evaporation, before the trans-esterification. In order to avoid free fatty acid neutralization, vegetable oil with low free fatty acid content can be used.

Bioethanol/Biogas

Globally, above 250 billion metric tons of biomass abounds. Sources for bio-ethanol production are readily available in the agro-waste sector in all regions of Africa. Africa being agrarian in nature is highly endowed with different biomass from plants. These could be sourced easily from the fields, forest, sea, households, agro-processing plants and other environments in Africa.

Any type of animal or plant material that can be converted into energy is called biomass [54]. Wastes from biomass can also provide raw materials for a diversity of bio-based products. For example, plastics from biomass are being produced using polylactic acid from corn [55]. According to Block [56] executive order and proposed bill will boost bio-based products and bioenergy in nations that sees the

need for it. Some of the biomass are: agricultural wastes, such as rice husks, corn stalks, straw, sugarcane leavings, bagasse, nutshells, and manure from cattle, poultry, and hogs; forestry residues, such as wood chips, bark, sawdust, timber slash, and mill scrap; municipal waste, such as waste paper and yard clippings are generated every year world over, especially in Africa from Agriculture [57]. Agricultural biomass wastes equivalent to approximately 50 billion tons of oil [58], converted to energy can substantially displace fossil fuel, reduce emissions of greenhouse gases and provide renewable energy to some 1.6 billion people in developing countries, which still lack access to electricity. As raw materials, biomass wastes have attractive potentials for large-scale industries and community-level enterprises. Some of the agricultural (food) wastes which could be put into useful purposes are as follows.

Rice husks: These abound in rural rice mill all over Nigeria and could be obtained at no cost since they are great burden to the rice millers taking up space and constitution pollution nuisance. Rice husks are disposed by incineration and dumped are various sites away from the rice mills. Many products have been developed from this greatly available and neglected agricultural waste. In Asia, Europe, South and North America, rice husks has been put into many uses such as fuel for cooking, briquette production, cement compounding, acoustic production, roofing tiles and even building of houses. Current studies on the usefulness of rice husks are in the possibilities of generating biofuels such as bioethanol, cellulose production, lignin generation, lignocellulose and sugar alternative source as well as biogas generation.

Citrus pulp and citrus molasses: Citrus pulps are biowastes which are the aftermath of the production of citrus juice. It is thus the other components (biowaste) apart for the juice needed by the citrus juice producing industries. Okonko et al. [55] reported the work by Wing [59] and Wing et al. [60], of the Florida Citrus Exchange which established a fellowship for research into uses of citrus waste in 1911 and thus launched an area of investigation which remains strongly productive. The research centered on citrus pulp, consists mainly of the rag, peel, and seeds of oranges with minor amounts from other fruits [61].

A possible research is the conversion of the excess pulp waste into bioethanol for chemical analysis in industries and laboratory. It could also be dried and grounded followed by treatment with microorganism for production of other non-nutritive value such as glucose or fructose for industrial and laboratory analysis purposes after purification [55].

In the beverage-alcohol industry, citrus molasses also serves as a substrate for fermentation. Moreover, Okonko et al. [55] stated that the remaining distillery waste can be condensed to a very acceptable feedstuff high in pentose sugars and, because of yeast used for fermentation, high in good quality protein. Large and increasing amounts of citrus molasses are used for production of beverage alcohol. The remaining sugars, which are pentoses, cannot be used by the beverage industry, but as feed stock for bioethanol. There is also a great potential for lignocellulose utilization of the citrus molasses for bioethanol and sugar synthesis [55].

Cassava wastes: Cassava is a major staple food in Nigeria and therefore produces large volumes of wastes, which has been creating environmental nuisance in the region [62]. Cassava (*Manihot esculenta* Crantz), is a major staple food in many tropical countries like Nigeria and therefore produces large volumes of wastes, which has been creating environmental nuisance in the region [63]. Disposal of agricultural byproducts such as cassava wastes from processing activities is becoming a concern in Nigeria due to its foul odour [55].

Bioconversion of these low-value cassava wastes, fibre components, and tuber peels discarded while processing as well as stem and leaves into lignin, cellulose, sugar and bioethanol is a worthwhile scientific investigation considering the volume of cassava produced in Nigeria annually especially those aspect not involved in food production. Okonko et al. [55] stated that in gari-producing communities' huge amounts of this effluent are generated and constitute an environmental menace. In Nigeria, high levels of gari effluent are produced daily and carelessly drained onto roads, streets, rivers and agricultural lands, thereby, constituting a serious environmental hazard. Not only does the effluent result in a strong stench, it could also result in loss of aquatic life because it is toxic.

Okonko et al. [55] reported that Uzochukwu et al. [64] carried out an investigation into the possibility of producing a useful product from gari industry effluent, which is an environmental menace, using a fermentation process. The effluent starch with an initial HCN concentration of 9 mg/ml was gelatinized by cooking, hydrolyzed using commercial alpha and beta amylases and fermented with *Saccharomyces cerevisiae* from palm wine. The fermented broth was distilled in the presence of dry orange peel; ethanol content was 50.1% (v/v). According to Uzochukwu et al. [64], sensory evaluation showed that the product was moderately acceptable, though the ethanol yield was low. This showed that maximum starch conversion to fermentable sugars by the commercial alpha and beta amylases occurred at the 90th minutes with sugar concentration increasing from the initial 3% to 23% suggesting that any residual cyanide did not inhibit the amylases. They concluded that the environmentally undesirable gari effluent can be given economic value by being converted to portable spirit which can be employed for the preparation of various beverages and foods as well as pharmaceuticals for internal consumption and perhaps best as bioethanol for automobile fuel uses. The process also detoxifies the final effluent, making it safe for discharge into streams and rivers [64].

Corn cobs/local plant tubers: Maize is one of the most cherished grains in Nigeria due to its ease of production and preparation as food. The bulk production of maize in Nigeria is from the Northern region where mechanized cultivation is practiced in comparison to the subsistence and minor commercial production in the Southern part of the country. The concern of the farmers is mainly in extraction, processing and marketing of the grain. The Corn cobs are littered and heaps could be found in farmland and rural areas. Disposal is by burning and incineration [55].

However, corncobs waste produced from an agricultural extraction of the maize grains was converted into fermentable sugars by the pretreatment processes of dilution with distilled water and the action of concentrated hydrochloric acid respectively [65]. According to Ashiru [65], the presence of these fermentable sugars i.e. hexose sugars and additional nutrients added to this substrate, were then utilized each by two yeasts, *Candida albicans*, *Saccharomyces cerevisiae* and a mould, *Neurospora crassa* with eventual conversion into ethanol after incubation for 96 hours at a temperature of 37°C.

Sugarcane bagasse and sugar cane molasses: Sugarcane bagasse is also a waste product generated in large quantities in Nigeria and is classified as lignocelluloses. It is consumed locally by the indigenes all over the country by chewing and sucking the juice (sucrose) from the cane. There are also a handful of sucrose processing industries in the country that use the cane sugar as raw industrial materials. Sugar cane bagasse was acid hydrolyzed by Ashiru [65] to obtain glucose and pentose sugars. The highest yield and productivity was recorded with the fungus *Neurospora crassa* using sugarcane bagasse with values being 77.88 g l⁻¹ [65]. At the end of acid hydrolysis, detoxification was carried out for all substrates using potassium hydroxide and then addition of other nutrients to increase yield and facilitate better fermentation [66].

There has been continuous production of citric acid from sugar cane molasses as reported by Gupta [67] using a combination of submerged immobilized and surface stabilized cultures of *Aspergillus niger*, KCU520. Molasses are wastes products produced from sugar refineries. Being an agricultural waste it is readily converted into fermentable sugars by the pretreatment processes of dilution with distilled water and the action of concentrated hydrochloric acid respectively. The presence of these fermentable sugars i.e. hexose sugars and additional nutrients added to these substrates, were utilized each by two yeasts, *Candida albicans*, *Saccharomyces cerevisiae* and a mould, *Neurospora crassa* [66] and converted into ethanol after incubation for 96 hours at a temperature of 37°C. *Neurospora crassa* produced the highest percentage yield of ethanol from the substrates, with 33.65% yield. *Candida albicans* produced the lowest percentage yield with 14.46% from molasses. *Saccharomyces cerevisiae* produced a percentage 23.59% ethanol from molasses [66].

Yam tubers waste: Two species each of yam (*Dioscorea rotundata*) and (*Dioscorea alata*) which are local common plant tubers in Nigeria are annually cultivated in Nigeria mostly from the Northern part of the country. North eastern and middle belt region of Nigeria are currently the leaders in the production of yam. Yam being a great source of carbohydrate is no doubt a good bio-ethanol source should research extension be a priority in this area in Africa.

Cocoyam tubers: This perennial plant is used domestically in the preparation of soup, fufu and other delicacies in Nigeria. It is an important food plant in Nigeria especially in Eastern Nigeria where it is mainly used for preparation of special soup dishes. Cocoyam (*Colocasia esculenta*) is an edible root crop belonging to the family *Aracea* commonly found in Nigeria and consumed when boiled in Northern Nigeria. Cocoyam makes significant contribution both as root crops and vegetables in the diet of people, particularly Nigerians and Africans at large [55]. The percentage of starch (72%) in cocoyam was exploited in the production of ethanol and vinegar [68]. This was achieved by two distinct biochemical processes brought about by the action of microorganisms under controlled environmental conditions. The first process called alcoholic fermentation was brought about by yeast (*Saccharomyces carlsbergensis*) and the second process acetic acid fermentation (acetification) was brought about by an acetic acid

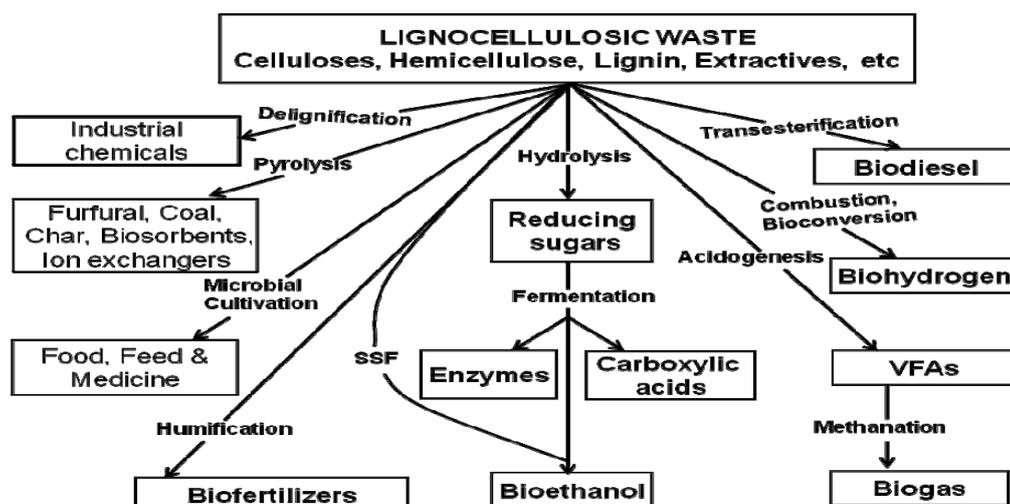


Figure 6: The main value-added products from lignocellulosic wastes (SSF = simultaneous fermentation and saccharification, VFAs = volatile fatty acids) [71].



Figure 7: Industrial size biogas plant in Kenya [73].

bacterium (*Acetobacter sp.*). Saccharification of gelatinized mash undergoes two (2) stages of enzyme hydrolysis, namely bacteria alpha-amylase and fungal alpha-amylase to produce fermentable sugars. The volume of production of Cocoyam in Nigeria presently however, will not be considered economical in the production of biofuels since it is still inadequate for local consumption [69].

Soy whey/soybean curd residue: Many Nigerian companies like Grand Cereal Oil Mills, Ltd, Jos – Plateau State use soy bean as their basic raw material for production of vegetable oil from the roasted soy seed. The wastes are converted into Grand Feed (Commercial Poultry feeds). Despite these two basic uses of soy bean, there are still excess soy curd residues as well as the whey produced which are underutilized. These can be used in the production of biodiesel and biofuels. Agarose-entrapped *Aspergillus niger* cells has been used for the production of citric acid from soy whey [70]. Soybean curd residue supplement has been found to be very significant for enhancement of methane production from pretreated woody waste [70].

Mango peels: The use of fermented mango peels (*Mangifera indica-R*) as source of bio-ethanol should be give good consideration. In Africa, the quantity of ripe mango fruits wasted, pre and post-harvest is enormous and therefore could be integrated into bioethanol production. Okonko et al. [55] stated that investigation into the pulp and molasses of mango waste from juice processing industries could be utilized for biofuel purposes, especially, bioethanol and biomethanol production.

Banana agro-waste: Banana is abundant in West African region

and grows very well in all part of Nigeria. It is a major cash crop of this region generating vast agricultural waste after harvest. The ripe banana peels are feed to domestic animals and is a rich source of vitamin and sugar which could be exploited for bioethanol production. The agro-waste including dried leaves and pseudostem after harvest was used as substrate for the release of sugars [55] hence bioethanol production possibilities. Thus, under these conditions the agro-waste left behind for natural degradation can be utilized.

Cashew fruit: This important food plant is found mainly in the Eastern, Western and Southern parts of Nigeria. The fruit easily deteriorates when it ripens and falls off from the tree of its own accord. Due to the soft fleshy fruit it is as good as not edible when it is not harvested since it easily bursts and oozes out the sugary fluid within its fruit. Most Nigerians are much more interested in the Nuts which are roasted and sold commercially as a major snack in Nigerian cities. Most often the seeds are extracted and the fruits left in heaps to decay, to be used as manure in rural areas where they abound. The fruits are also consumed by humans and fed to domestic animals. This is a good source for exploitation in the production of bioethanol since it is readily available seasonally every year in large quantities in Nigeria. It has excellent sugar content [71,72].

Biosolids: Biosolids are nutrient-rich, predominantly organic materials (leave, vegetables, cobs, peels, seeds, wood bits etc). They are made up of mixture of agricultural waste constituting food wastes, biomass and agro-processing wastes. Although classified as a waste material, biosolids can be a beneficial agricultural or horticultural resource because they contain many essential plant nutrients and

organic matter. Biosolids are also good sources for the generation of biogas such as methane which could be harnessed for domestic purposes.

Lignocellulose as a resource for bioproducts: Many lignocellulosic (plant biomass made up of lignin, cellulose and hemicellulose) waste materials abound in Africa. Figure 6 illustrate possible product of lignocellulosic wastes provided the conditions for conversion are met. Most of the techniques illustrated are already in great application in developed countries and fast developing technology and economic regions of the world like Malaysia, India, Brazil, USA, China and Norway.

Sources of some of these lignocelluloses which abound in Africa includes: palm fruit husks, peanut shell/pod, palm kernel cake waste, rice straw, rice husk, stems of plants, leafy materials and many others. These can all be bio-converted into various fine chemicals and biological products of importance. Thus concerted research being the aim of this paper especially those indigenous to Africa is encouraged to turn these wastes and environmental nuisance into wealth. In the context of this chapter, lignocelluloses should be researched for possible conversion into bioethanol and biogas.

An innovation into biogas production in Africa was reported by Kothanikkal [73]. The author explained that a biogas plant will be built on the premises of the largest producer and exporter of processed food (fruits, beverages, etc.) in Kenya. The biogas plant will have an installed capacity of nearly 5 MWel. The biogas plant will use waste from the food processing and field waste as a substrate (Figure 7). This specific waste (e.g. pineapple) is not used as a substrate as of now. AgriKomp tested the substrate with very good results in terms of biogas standard volume and organic dry substance (ODS) figures. The biogas plant will have four digesters and 2 post-digesters and will roughly produce more than 21,000,000 m³ of biogas per year [74].

Conclusion

Africa may not be technologically advance, but the fact that it is a leader in provision of alternative raw material for petroleum generation is never in doubt. The place of most African community in technological utilization of energy from biomass is far from acceptable in the present times. This write-up is therefore an insight into the biomass availability sources in Africa as well as a call both on Africans and the developed countries to harness the resources so as to avert world shortage of energy fuel from non-renewable petroleum (fossil oil) source.

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