ARID ZONE JOURNAL OF ENGINEERING, TECHNOLOGY & ENVIRONMENT
AZOJETE, March, 2019. Vol. 15(1):153-162
Published by the Faculty of Engineering, University of Maiduguri, Maiduguri, Nigeria.
Print ISSN: 1596-2490, Electronic ISSN: 2545-5818
www.azojete.com.ng

ORIGINAL RESEARCH ARTICLE

A REVIEW OF BIOFUELS RESEARCH IN NIGERIA

T. E. Odetoye*, E. O. Ajala and D. S. Ogunniyi

(Department of Chemical Engineering, University of Ilorin, PMB 1515, Ilorin, Nigeria)

**Corresponding Author: todetoye@yahoo.com*

ARTICLE INFORMATION

Submitted 28 March, 2018
Revised 15 December, 2018
Accepted 19 December, 2018

Keywords:
Biofuel
Research
Industry
Production
Nigeria

ABSTRACT

Biofuels are attracting a lot of research attention as a source of renewable energy due to environmental benefits and prospects of energy security. The expectation of the global community is particularly high towards Sub-Saharan African countries like Nigeria to meet the growing bioenergy needs by harnessing the abundant supply of biomass feedstock. However, lack of home-grown technology has been one of the major drawbacks of biofuel industrialization in Nigeria. Although a reasonable amount of biofuel research effort has been embarked on locally in Nigeria, most of these research works have remained on the shelf instead of being translated into commercial production. This paper reviews some biofuel research work done on Nigerian biomass. It recommends that funding the existing and new biofuel research work in Nigeria and channeling research towards industrialization as important drivers towards biofuel production in Nigeria.

1.0 Introduction

The global challenge of climate change due to over-dependence on fossil fuel has necessitated the shift towards renewable fuel (IRENA, 2015). Renewable energy has become the fastest growing source of energy globally and its share in the primary energy source has been projected to increase to 10% by the year 2035. Moreover, the projected industrialization of Africa is expected to further increase the global energy demands by 2035 (Dudley, 2017). Biofuels which are alternative fuels derived from biomass include gaseous, liquid or solid fuels like biogas, biobutanol, biodiesel, bioethanol, bio-oil that are produced from biological materials. Biofuels can be used for generating power and heat (Agbro and Ogie, 2012). Biomass can be defined as a material derived from recently living organisms which include plants, animals and their by-products, e.g. manure, garden waste and crop residues (Asfar, 2014). Biomass has been regarded as one of the renewable energy source which has the potential of meeting the global energy targets (EIA, 2013).The attending benefits of biofuels have been observed to go far beyond the clean burning nature of the product since biofuel's renewable resource can help to create a market for farmers and reduce the amount of waste oil, fat and grease being dumped into landfills and sewers (Idusuyi et al, 2012).

According to research trend on biofuel feedstock and conversion technologies, biofuels are categorized as first, second and third generation biofuels. First-generation biofuels are produced mainly, from food sources such as sugar, starch, and vegetable oil while the second-generation

are from dedicated bioenergy crops, non-food feedstock such as ligno-cellulosic biomass (agricultural and forestry feedstock) and other food processing biomass residues. Third generation biofuels are produced mainly from aquatic feedstock such as algae (Beetul, 2014; Saladini et al., 2016). It is note-worthy that the food-fuel debate has favoured the preference for the second and third generation biofuel production (Galadima, 2011) and the need for sustainable alternative biofuels had kept the interest of stakeholders and researchers in second-generation biofuels (Saladini et al., 2016).

Nigeria has been regarded as one of the countries that have the potential to produce sufficient biofuel for both domestic use and export (Elijah, 2010; Abro and Ogie, 2012) considering her agricultural land area of approximately 71,000,000 ha of which about 37.3% is arable land available for cultivation of biomass for biofuel (Ben-Iwo et al., 2016). However, the structure of the Nigerian economy has been heavily dependent on fossil fuel which accounted for up to 95% of the country's export earnings (Chete et al., 2013), while the agricultural sector accounted for about 2% of the total export (Kale, 2016). Recently, Nigeria faced an economic challenge as a result of over-dependence on crude petroleum for export earnings. Whereas, production of biomass feedstock/biofuel, among other bio-based products, is a potential source of additional export earnings. There is need to develop existing biofuel research in Nigeria into commercial production for domestic use and to attract foreign exchange for the Nigerian economy. This work is aimed at reviewing the earlier works on biofuel production in Nigeria and the prospects of commercialization of biofuel production in the country.

2.0 Biofuel Research in Nigeria

2.1 Potential Feedstock

Potential crops for biofuel production as earmarked in the Nigerian National Petroleum Corporation (NNPC) biofuel policy include sorghum, sugarcane, cassava and jatropha. While some food crops are currently been utilized as biofuel feedstock in the developed and emerging economies such as U.S., India and Brazil, the food fuel debate has been a major consideration identified so as to avert food crisis in Nigeria and the African continent in general.

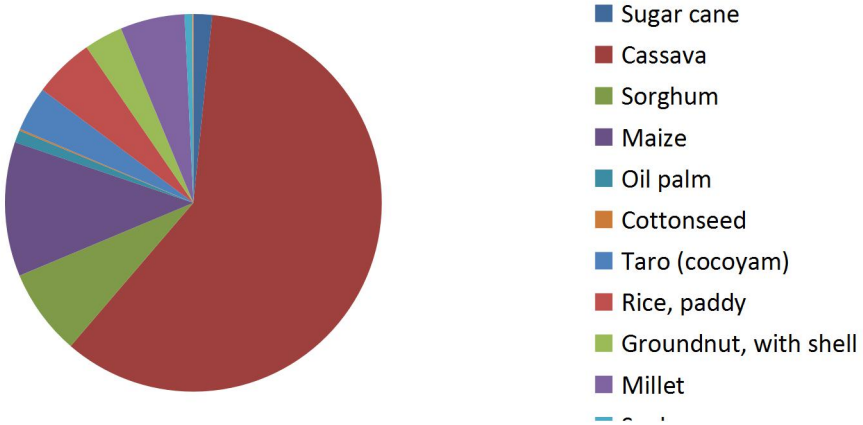

Figure 1: Bioenergy crop production in Nigeria

Source: Ben-Iwo et al., 2016

Figure 1 shows the percentage production of some Nigerian food crops that are considered as feedstock for biofuel production that may pose food-fuel challenge in Nigeria.

First generation biofuel production which is usually based on the use of food crops as biofuel feedstock, has been criticized as non-suitable for Nigeria, a developing country like (Galadima et

al., 2011). Other feedstock that have been reported as suitable for biodiesel production include soybean (US), rapeseed (Europe), oil palm (South-East Asia), Jatropha and rice bran oil (India). Biodiesels have also been produced from canola oil, waste restaurant oil, animal fat, rapeseed oil and palm oil. The potential biomass resources in Nigeria include wood, charcoal, grasses and shrubs, agricultural residues, forestry residues, municipal biomass wastes, industrial biomass wastes and aquatic biomass (Abro and Ogie, 2012). Agricultural residue, crop residue and agro-industrial by-products such as cocoa husk, coconut shell and husk, rice husks, oil seed cakes and oil palm empty fruit bunch have been investigated towards the production of biofuel.

Furthermore, cassava residue has been recognized as one of the major agricultural crop residues in Nigeria with an estimated value of 29 metric tonnes per annum of residues generated. Municipal solid wastes can also serve as potential feedstock for biogas production by anaerobic digestion with over 25 million tonnes of municipal solid wastes generated per annum in Nigeria. The waste can be converted to wealth in biofuel production (Agbro and Ogie, 2012).

Many researchers have worked on generating biofuel from locally available Nigerian biomass feedstock, ranging from agricultural residues to food and non-food biomasses. Table 1 summarizes some recent biofuel research efforts in Nigeria.

Table 1: Some recent biofuel feedstock research efforts in Nigeria

Biofuel Feedstock	Biofuel Type	Method of Production	Workers
Palm kernel oil	Biodiesel	Transesterification	Igbokwe Nwafor,2014
Mango seed oil	Biodiesel	Transesterification	Umaru et al., 2014
Coconut oil	Biodiesel	Transesterification	Alamu et al., 2010
Peanut oil	Biodiesel	Transesterification	Ajala et al., 2014
Soy bean oil	Biodiesel	Transesterification	Fasogbon & Asere, 2014
Sugarcane	Bioethanol	Fermentation/ pilot plant	Misau et al., 2012
Milk bush oil	Biodiesel	Transesterification	Oniya et al., 2016
Jatropha oil	Biodiesel	Transesterification	Ameen et al, 2014
Tobacco seed oil	Biodiesel	Transesterification	Motojesi et al, 2017
Shea butter	Biodiesel	Transesterification/ processor	Ajala et al, 2015
Parinari oil	Biodiesel	Transesterification catalyst	Aladetuyi et al, 2014
Parinari residue	Bio-oil	Pyrolysis	Odetoye et al, 2014
Parinari oil	Biodiesel	Transesterification pilot plant	Odetoye (ongoing)

Palm kernel oil biodiesel was produced through transesterification by ethanol using NaOH catalyst (Alamu et al., 2008). The properties of the fuel produced were in good agreement with the American Society for Testing and Materials (ASTM) standards. The fuel characteristics of the biodiesel produced demonstrated that the PKO biodiesel produced can be used as fuel in diesel engines.

Umaru et al. (2014) reported the suitability of mango seed oil for biodiesel production. A biodiesel yield of over 80% wt was obtained at an optimal temperature of 60°C. The biodiesel produced was reported to be consistent with the threshold standard values quoted by ASTM and EN for biodiesel and fossil diesel. Coconut oil was also found suitable for biodiesel

production (Alamu et al., 2010). A blend of the coconut oil biodiesel with petroleum diesel was reported to be suitable as alternative to diesel.

Table 2: Physical property of some biodiesels from various feedstock

Physicochemical Property	Peanut biodiesel	Soybean biodiesel	Sunflower biodiesel	Petroleum diesel	Palm biodiesel	Babassu biodiesel	Rapeseed biodiesel
Density at 40°C [kgL^{-1}]	0.833	0.885	0.860	0.823	0.855	0.875	0.882
Viscosity [40°C, mm^2/s]	4.9	4.5	4.6	4.0	4.5	3.6	4.2
Flash Point [°C]	176	178	96	98.0	174.0	127	80
Cloud Point [°C]	5	1	-	18.0	16.0	-	-
Pour Point [°C]	-	-7	-	15.0	16.0	-	-
Cetane Value	564	43	49	53	65	63	54
Sulfur Content [wt %]	-	-	-	0.10	0.04	-	-
Carbon Residue [wt %]	-	-	-	0.14	0.02	-	-

Source: Ajala et al., 2015

Aladetuyi et al. (2014) have reported the utilization of cocoa pod ash (CPA) an agricultural residue which was used in place of KOH as a conventional catalyst for bio-diesel production. The findings of the study suggested that the use of cocoa pod ash as catalyst led to higher yield of biodiesel both from palm kernel oil and oil recovered from spent bleaching earth. The physico-chemical properties of the biodiesels produced was reported to fall within (ASTM) specifications for biodiesel. It was also reported that agricultural residues such as CPA could be utilized as alternatives to KOH catalyst for biodiesel production (Aladetuyi et al., 2014). Olugbenga et al. (2013)) also reported that a good biodiesel conversion of 94% yield was achieved when cocoa pod ash was used as catalyst for biodiesel production.

In a recent study (Odetoye et al., 2014), bio-oil was obtained from a non-conventional agricultural residues, Parinari polyandra Benth fruit shell (PPBFS). PPBFS was pyrolyzed via an intermediate pyrolysis process for the production of bio oil. The bio oils were obtained using a fixed bed reactor within a temperature range of 375–550°C.However, the PPBFS bio-oil needs to be upgraded before being used as a fuel substitute, particularly in engines as it consisted of various complex organic compounds such as acetic acid (Odetoye et al, 2014).

Production of biodiesel from yellow oleander, Theveta peruviana has been reported to have a high potential for use in production of environmentally friendly biodiesel (Yarkasuwa et al., 2013). Both ethanolysis and methanolysis of the oil were carried out with 50% of potassium hydroxide by weight of oil in ethanol and methanol respectively. The biodiesel was tested for biodegradability using E. coli. The percentage yield of the fatty acid ethyl esters and fatty acid methyl esters were 84.8% and 91.6% respectively.

Amos et al. (2015) also reported that Parinari polyandra Benth seed oil can be explored for biodiesel production. Some bio-based catalysts (cocoa pod ash and rice husk ash (RHA) were used to catalyze effectively the transesterification of parinari oil. Although, the two bio-based

catalysts were effective, CPA gave a neater and better yield of biodiesel than RHA. The biodiesels produced were reported as suitable for biodiesel production as properties compared favorably with ASTM specification for biodiesel standards.

2.2 Industrialization of Biofuel Research in Nigeria

Several attempts were reported on commercialization of biofuel research in Nigeria. Some of the works reported include that of Akinbami et al. on the design of biogas plants at the Usman Danfodiyo University, Nigeria. A 425 litres capacity biogas digester was found to be adequate for household cooking energy need in Nigeria (Akinbami et al., 2001). Recent experimental efforts have been reported at the University of Nigeria, Nsukka and at the Global Network for Environment and Economic Development Research (GNEEDER) in Ibadan, Nigeria for developing appropriate technological innovations for harnessing existing potentials for producing biogas, particularly for household use.

Furthermore, there is domestication of biogas technology in Nigeria (Olugasa et al., 2014). The Nigerian Universities have taken up the challenge on biogas research by constructing biogas digesters and/ or pilot biogas plants at the University of Ilorin, Obafemi Awolowo University, Ladoke Akintola University of Technology, Ogbomoso, Ambrose Ali University, Nnamdi Azikwe University, Awka, Uthman Dan Fodio University, Ibrahim Badamasi Banbangida University, Lapai, but to mention a few. The non-governmental organizaions are not left out in the development. Most of these pilot biogas plants have been developed to use animal wastes as feedstocks (Olugasa et al., 2014). The recent trend in biogas research is increasing the yield and enrichment to increase the biogas purity. The biomethane obtained can be converted to serve as source of electricity for household appliances (Olugasa et al., 2014).

Government research institutions and industrialization of biofuel research in Nigeria.

One of the major roles of research institutions is to carry out research towards the development of the immediate community. However, presently, the researches on biofuel are not adequately co-ordinated. There is a need for significant centers of excellence for biofuel research as well as dedicated funding for biofuel research in the science, technology and innovations (STI) institutions.

Moreover, the Government and policy makers have major roles to play in the commercialization of biofuel production in Nigeria. The initial take off of the biofuel project in Nigeria came with enthusiasm and strong political will with about 34 current and proposed biofuel plant projects as pioneer projects at planning phase, however with the passage of time the tempo was not sustained (Elijah, 2010). The government STI policy and biofuel policy lack the political will for actualization of the policies. There is a need for the Government to float / reactivate existing bioenergy parastatal to collate a database of biofuel research in Nigeria. Such Government functionary should be responsible for driving the biofuel research incubation and commercialization. There is a need to review the biofuel and STI policy to reflect the devoid of first generation biofuel.

Opportunities of biofuel industrialization in Nigeria

The opportunities accruable to biofuel industrialization in Nigeria mainly span across, economic, environmental and social dimensions (UNDESA, 2007). There are opportunities of rural

development when biofuels are substantially produced in Nigeria as more biofuel feedstock will be produced and thus lead to strengthening of the Nigerian agro-economics. There will be provision of jobs for teeming youths and peasant farmers in the rural setting. Rural-urban migration of the youths will also be minimized since agricultural sector will be enhanced and the rural youth will be involved in biofuel feedstock production.

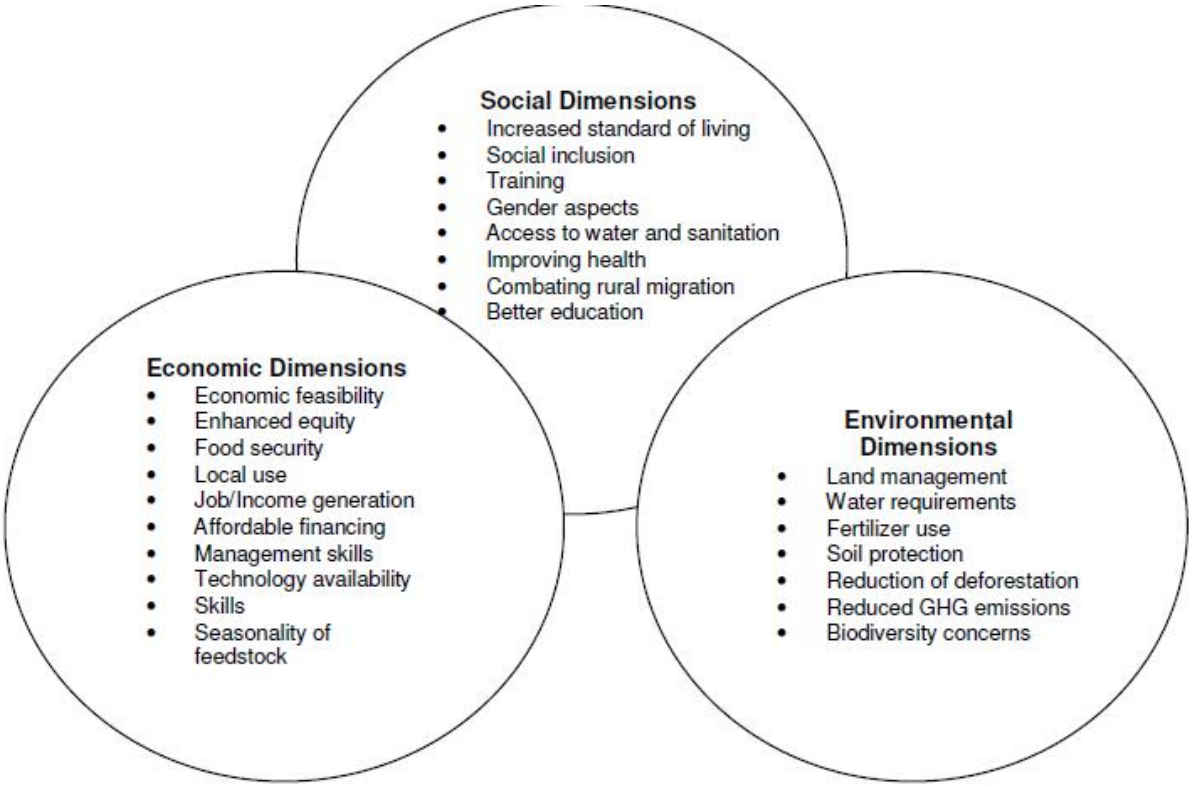

Figure 2: Criteria for sustainable production and use of liquid biofuel (UNDESA, 2007)

In fact, industrialization of bioenergy production in Nigeria can be a means of improving the economic status of farmers due to increased income realized from biofuel feedstock production. Figure 2 shows the criteria for sustainable biofuel production.

Challenges of biofuel industrialization in Nigeria

The problems facing biofuel industrialization in Nigeria are typical of those problems facing all forms of industrialization in Nigeria. The problems ranged from lack of co-ordinated research work in biofuel leading to duplication of research efforts, inadequate funding of biofuel research, lack of home-grown technology, non-commercialization of biofuel research ideas to the relatively high cost of biofuel compared to fossil fuel. Furthermore, the low-income people seem to be more dependent on traditional energy more than liquid biofuel as source of energy (Akande and Olorunfemi, 2009).

Recommendations

The government has a paramount task in establishing industrial production of biofuel in Nigeria. Many of the existing research output on biofuel should be adopted and scaled up to commercial scale. This is to be co-ordinated by the appropriate dedicated and functional Government

agencies and research outfits. The administration and monitoring of the biofuel policy should be taken out of the NNPC to encourage pragmatic attention for biofuel production. There is a need to review the existing Nigerian biofuel policy to accommodate the research outputs on the utilization of some locally available biomass feedstock for sustainable biofuel production. The use of non-food feedstock should be promoted to reduce competition with food chain. There is also a need to ensure that the biofuel policy does not end up as mere paper work but consistently followed up through to implementation.

Much more, the academia should be funded and saddled with the responsibility of directing more effort into biofuel research and development which can translate the varieties of our tropical biomasses into biofuel feedstock. Centers of Excellences should be established in at least each political zone, fostering biofuel research consortium towards building a home grown technology for the Nigerian biofuel industry.

Small-scale biodiesel production from the farms can also be encouraged by providing portable biodiesel processor which can be affordable to farmers in rural settlements. The production technologies of biodiesel are relatively not complex for the developing economy to adopt both at small-scale production and industrial scale. This is an advantage that can be utilized in Nigeria and other African countries for biodiesel production.

There should be pragmatic approach to implementing the biofuel policy. According to the Biofuel Policy, the roles of the Biofuel Energy Commission were specified to include monitoring the supply and utilization of biofuels and biofuel blends in Nigeria. Furthermore, there is a need to review the 2007 biofuel policy to accommodate recent trends in biofuel development especially in the area of fourth generation biofuels as the 2007 policy was mainly based on third generation biofuel. The tax with-holding and tax holiday incentives will be a very encouraging support for the upcoming biofuel industries but there is need for research towards establishing non-edible biomass feedstock to avoid competition with food source.

The agricultural system needs to be revitalized for both food and industrial crops and exports. There is a need for large scale growing of biomass feedstock both by peasant and large scale farmers to support the biofuel industry. The economic status of such peasant farmers will then be enhanced. For consistent supply of cheap feedstock for biofuel production, municipal solid wastes collection system should be restructured to encouraged separation of organic components from source so as to utilize them for biogas production. Agricultural wastes should also be explored for industrial biofuel production.

All existing biofuel research on Nigerian biomass should be well-documented and well-archived in a database for easy documentation and retrieval of local biofuel information. Also, centers of excellence for biofuel research should be established and more research should be directed towards establishing new and cheaper feedstock as energy crops and discovery of more economical methods of biofuel production. The improvement in production economy will include sourcing for potential feedstock with more biofuel yield, cheaper catalysts and cheaper source of energy inputs.

The linkages between researchers, faculties of engineering and the industries should be strengthen and there should be synergy in the co-ordination of funding of research and research commercialization among national economic empowerment and development strategy (NEEDS), TETFUND, BOI, Small and Medium Industries Development Agency (SMEDAN) Manufacturers Association of Nigeria MAN Federal Ministry of Agriculture and Rural Development.

4.0 Conclusion

This review work indicates that a reasonable number of indigenous biomass has been investigated and found suitable for biofuel production. However, these biomass are yet to be adopted as biofuel feedstock in Nigeria. One of the major ways of actualizing the industrialization of biofuel production in Nigeria is to adequately fund biofuel research, utilizing indigenous feedstock and home-grown technology. More research should be funded towards identifying more of the sustainable, non-food biofuel feedstock, pilot scale research and scaling up of the existing research outputs towards commercial scale. There is a need to engage in Design and construction of portable scale biodiesel plants from cheap and locally available materials, plants which can be operated by SME's. Such move will position biofuel production in Nigeria as a laudable step towards the revitalization of the agricultural sector which erstwhile had been neglected.

Considering the very high potential for biofuel production in Nigeria, all hands should be on desk to ensure the effective commercialization of biofuel research, converting the existing research from bench scale to commercial scale. This will go a long way to enlist Nigeria as an exporter of biofuel and improve the dwindling foreign reserve. Production of feedstock for biofuel production will enhance the agricultural sector of the country which has been suffering a setback as a result of the over-dependence on petroleum.

Acknowledgement

The contributions of the participants /discussants at the 6th Regional Conference of Vice-Chancellors, Deans of Science, Engineering and Technology (COVIDSET), 2015 towards enhancing this work are well appreciated.

References

Agbro, EB. and Ogie, NA. 2012. A comprehensive review of biomass resources and biofuel production potential in Nigeria, Research Journal in Engineering and Applied Sciences 1(3): 149-155.

Ajala, OE., Aberuagba F., Odetoye, TE. and Ajala, AM. 2015. Biodiesel: Sustainable energy replacement for petroleum based diesel fuel - A review, ChemBioEng Reviews, 2(3): 145-156.

Akande, SO. and Olorunfemi, FB. 2009. Research and development potentials in biofuel production in Nigeria. African Research Review, 3 (3): 34-45.

Akinbami, JFK., Ilori, MO., Oyebisi, TO., Akinwuni, IO. and Adeoti O. 2001. Biogas energy use in Nigeria: current status, future prospects and policy implications. Renewable,Sustainable Energy Review. 5: 97-112.

Aladetuyi, A., Olatunji, GA., Ogunniyi, DS., Odetoye, TE. and Oguntoye, SO. 2014. Production and characterization of biodiesel using palm kernel oil, fresh and recovered from spent bleaching earth and Biofuel Research Journal, 1(4):134-138.

Alamu, OJ., Dehinbo, O. and Sulaiman, AM. 2010. Production and testing of coconut oil biodiesel fuel and its blend, Leonardo Journal of Sciences, 16: 95-104.

Amos, O., Ogunniyi DS. and Odetoye TE. 2015. Biodiesel production from Parinari polyandra seed oil using bio-based catalyst, Nigerian Journal of Technological Development 13 (1): 26-30.

Asfarn, JA. 2014. Gasification of Solid Waste Biomass, Jordan Journal of Mechanical and Industrial Engineering , 8 (1):13-19.

Beetul, K., Sadally, SB., Hossenkhan, N. and Puchooa, D. 2014. An investigation of biodiesel production from microalgae found in Mauritian waters. Biofuel Research Journal, 2:58-64.

Ben-Iwo, J., Manovic, V. and Longhurst, P. 2016. Biomass resources, and biofuels potential for the production of transportation fuels in Nigeria. Renewable and Sustainable Energy Reviews, 63: 172–192.

Chete, LN., Adeoti, JO., Adeyinka, FM. and Ogundele, O. 2013. Industrial development and growth in Nigeria,: lessons and challenges, Learning to compete working paper 8, A publication of The Brookings Institution, 1-32.

Dudley B. 2017. B.P. Energy Outlook 2017. Edition, 86-89.

EIA 2013. The Annual Energy Outlook, U.S. Energy Information Administration (EIA),pp 75, The International Renewable Energy Agency.

Elijah, IO. 2010. Emerging Bio-ethanol Projects in Nigeria: Their Opportunities and Challenges. Energy Policy Reviews, 38 (11): 7161-7168.

Fasogbon, SK. and Asere, AA. 2014. Effect of Soya bean methyl ester on the performance characteristics of compression ignition engine, World Academy of Science, Engineering and Technology publication, 8(2):266.

Galadima, A., Garba, ZN., Ibrahim, BM., Almustapha, MN., Leke, L. and Adam, IK. 2011. Biofuels Production in Nigeria: The Policy and Public Opinions, Journal of Sustainable Development 4 (4): 22-31.

Idusuyi, N., Ajide. OO. and Abu, R. 2012. Biodiesel as an alternative energy resource in Southwest Nigeria, International Journal of Science and Technology, 2(5): 323 -326.

Igbokwe JO. and Nwafor MO. 2014. Synthesis and Characterization of Biodiesel from Nigerian Palmkernel oil, American Journal of Engineering Research 3(3): 264 – 266.

IRENA. 2015. Rethinking Energy: Renewable Energy and Climate Change, 9-11,www.irena.org/publications accessed on 9th March, 2017.

Misau, IM., Bugaje, IM., Mohammed, J., Mohammed, IA. and Diyau'deen, BH. 2012. Production of Bio-Ethanol from Sugarcane: A Pilot Scale Study In Nigeria, International. Journal of Engineering Research and Applications (IJERA),2 (4): 1142-1151.

Motojesi, O., Ogunniyi, DS. and Odetoye, TE. 2017 Trans-esterification of tobacco seed oil using some agricultural wastes as catalysts, Journal of the Nigerian Society of Chemical Engineers 32(1): 65-75.

Odetoye. TE., Onifade, KR., AbuBakar, MS. and Titiloye, JO. 2014. Pyrolysis of Parinari polyandra Benth fruit shell for bio-oil production, Biofuel Research Journal, 3, 85 - 90.

Olugasa, TT., Odesola, IF. and Oyewola, MO. 2013. Energy production from biogas: A conceptual review for use in Nigeria, Renewable and Sustainable Energy Reviews 32, 770-776.

Olugbenga, AG., Mohammed, A., and Ajakaye, ON. 2013. Biodiesel production in Nigeria using cocoa pod ash as a catalyst base, International Journal of Science and Engineering Investigations, 2(15): 114-117.

Oniya, OO., Adebayo, AO. and Ogunkunle, O. 2016. Optimization of biodiesel production from milk bush (Thevetia peruviana) oil using snail shell as catalyst, Advances in multidisciplinary & Scientific Research 3 (1): 9-22, 2016.

Saladini, F., Patrizi, N., Pulselli, FM., Marchettini N. and Simone B. 2016. Guidelines for energy evaluation of first, second and third generation biofuels. Renewable and Sustainable Energy Reviews, 66: 221–227.

Sekoia, PT. and Yoro, AO. 2016. Biofuel development initiatives in sub-saharan Africa: opportunities and challenges, Climate 4(33): 1-13.

Umaru M., Mohammed IA., Sadiq MM., Aliyu AM, Suleiman B. and Talabi, S. 2014. Production and characterization of biodiesel from Nigerian mango seed oil, Proceedings of the World Congress on Engineering, London, U.K.

UNDESA. 2007. Small-Scale production and use of liquid biofuels in sub-saharan Africa: Perspectives for sustainable development, Background paper No. 2, a publication of United Nations Department of Economic and Social Affairs, 31.

Yarkasuwa, CI., Wilson D. and Michael E. 2013. Production of biodiesel from yellow oleander *(Thevetia peruviana)* oil and its biodegradability, Journal of the Korean Chemical Society, 57(3): 377-381.