UNIVERSITY OF ILORIN

THE TWO HUNDRED AND FIFTY-THIRD (253RD) INAUGURAL LECTURE

“SYMPHONY OF BIOMASS, BIOENERGY AND BIOPRODUCTS FOR SUSTAINABILITY”

By

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DEPARTMENT OF CHEMICAL ENGINEERING,
FACULTY OF ENGINEERING AND TECHNOLOGY,
UNIVERSITY OF ILORIN, NIGERIA

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Members of my Nuclear and Extended Families,
Distinguished invited guests,
University of Ilorin Scholars,
Great Students of the University of Ilorin,
Gentlemen of the Press, Print and Electronic Media,
Distinguished Ladies and Gentlemen.

Preamble

I give glory to God, my glory and the lifter up of my head (Psalm 3:3) as I stand before you to deliver the 253rd inaugural lecture of this University today. I thank the Vice-Chancellor for this opportunity and I welcome you all. I thank God I have been able to bag a Bachelor's degree in Chemical Engineering, a Master's degree and two Doctorate degrees. My first Doctorate was obtained in the field of Chemistry about 16 years ago, while my second Ph.D. degree was obtained in Chemical Engineering. There are intersections in both fields, especially in the higher degree research works for collaborative approach (Ogunniyi, 2013). Indeed, the title for today's lecture is a symphony to both fields**.**

The Department of Chemical Engineering of the University of Ilorin came on board in 2008, and I was privileged to be one of the pioneer staff members. The pioneer Head of the Department and former Dean (FET), my mentor and "academic father", Prof. D.S. Ogunniyi, delivered the very first inaugural lecture. It was the 125th inaugural lecture of the University and it was delivered on the 21st March, 2013, titled: "My Adventure with Polymers". The second lecture was delivered by Prof. Omodele A.A. Eletta, the first female professor of the Faculty of Engineering and Technology, on the 2nd September, 2021 titled: "Bad, Yet Good: Rummaging and Combatting for Future Water and Land Security". Prof. S.A. Abdulkareem, my undergraduate project supervisor, a mentor and father, and the immediate past Vice Chancellor of the University of Ilorin, had earlier delivered the 82nd inaugural lecture on 10th May, 2007 then at the Department of Chemistry, titled "Making Stuffs, Hot Stuffs: the Power of Mind over Matter".

Today, I rejoice as I join the league of these giants and trailblazers before me to deliver the third inaugural lecture of the Department of Chemical Engineering and the 21st in the Faculty of Engineering and Technology. All the previous inaugural lecturers are my senior colleagues who imparted me in one way or the other. Prof. S.A. Abdulkareem mentored me in my undergraduate research as supervisor, and pursued my admission here for my M.Sc. in Industrial Chemistry. Professor D.S. Ogunniyi mentored me for both my Masters and Ph.D. programmes as my supervisor. He stood by me and encouraged me to keep on when the going got tough as a staff member, especially when I wanted to abandon the academic profession initially. Today, I thank God I rescinded that decision and I am forever grateful to him. I am especially glad that my mentor, Professor D.S. Ogunniyi is still in service at the University to witness my presentation today. I hope to make you all proud.

Introduction: My Journey into Bio-based Product Development

My first bioproduct was produced early in life; this was when I was introduced to the Junior Engineers, Technicians and Scientists (JETS) club as a Senior Secondary School student at Ilorin Grammar School. Then, I ventured to submit the call for science students' project exhibition. I can remember my submission of a primitive aqueous extract of some mosquito-repellant leaves that was supposed to be a bioinsecticide! Thanks to my classmates who tolerated the odour of "insecticide" which emanated from my class desk which I had turned into a "mini laboratory! Little did I know that God was ordering my steps to journey into bio-based product development through which I would one day become a professor! Meanwhile, I wanted to study to become a medical doctor which was the only course that was advertised to me as a young secondary school girl, though I was scared of working in a hospital environment! Being the overall best-graduating student who was awarded the best student prizes in English, Mathematics, Chemistry, Economics among others, it took the intervention of God through My Uncle and Aunt (Professor & Dr. Mrs. D.O. Alao) to be guided into the Chemical Engineering programme. That was the first time I heard about the name of the course. I am forever grateful for this god-sent guidance. Indeed, I have found more fulfilment today where God has ordered my step.

Concepts of Biomass, Bioenergy, Sustainability and Chemical Engineering

Mr. Vice-Chancellor, there is a growing need for environmentally-friendly replacements of petroleum-based industrial feedstocks with renewable materials. The global trend is to promote environmentally-safe practices and fuels to combat the menace of climate change and global warming. In the 21st century, sustainability has become a treasured core value of the United Nations for national and global development (Odetoye and **Odetoye**, 2021). Chemical Engineering is one of such disciplines that promote sustainability. Chemical Engineering has been defined as the application of basic sciences (chemistry, biology, physics, mathematics) and engineering principles to the development, design, operation and maintenance of processes; converting raw materials to useful products while ensuring that the environment is not compromised. The development of processes for converting biomass raw materials to bioenergy and bioproducts has been one of my research interests as a chemical engineering researcher. According to the American Institute of Chemical Engineers, chemical engineers are problem solvers who combine the science of chemistry with the discipline of engineering, they take chemistry out of the laboratory, apply it on a large scale and bring it to the world around by producing things we all use (AIChE, 2020).

Definition of Key Terms

Biomass in the context of bioenergy is a renewable organic material which originates from plants and animals. Meanwhile, plants and animals were made by God the creator on the third, fifth and sixth days of creation (Genesis 1:12-25). Biomass contains carbon, hydrogen and oxygen components resulting from the process of photosynthesis (EIA, 2023). Biomass for energy can be sourced from forestry and agricultural residues, crop cultivation wastes, animal manures, sewage sludge, solid wastes, vegetable oils and animal fats.

Bioenergy is the energy derived from biomass and it is obtained by converting the stored chemical energy within biomass into heat and other useful energy sources (Titiloye *et al.*, 2013).

Biofuels are fuels made from biomass which are used for automotive, thermal and power generation purposes. Biofuel is synonymous with biocrude, biodiesel, biooil, biogas, bioethanol, biosyngas, biochar and bioslurry fuels that are made through biochemical, chemical or thermochemical methods (**Odetoye***et al.*, 2020).

Bioproducts or Bio-based Products are industrial chemicals other than fuel, that are obtained from renewable biological resources or any domestic consumables manufactured with such chemicals and materials (Gao *et al.*, 2020). They include biosolvents, biolubricants, biosurfactant, bioplastics and biocatalysts.

Sustainability has been defined as meeting our own needs without compromising the ability of future generations to meet their own needs (Brundtland, 1987). Hence, the seventeen United Nations sustainable development goals were subsequently birthed in 2015.

Lignocellulosic Biomass Residues

Nigeria is endowed with an abundant supply of lignocellulosic biomass residues waiting to be harnessed in more environmentally friendly ways. However, the practice of open burning of these biomass residues has led to pollution of the environment especially in dry seasons (Chakravarty *et al*., 2024). Biomass sources such as grasses, forest and agricultural residues are regarded as lignocellulosic biomass and they are composed mainly of three main polymeric components; lignin, cellulose and hemicellulose which exist in varying proportions depending on the type of biomass. Eventually, the thermochemical properties of a particular biomass sample are part of the factors that influence the characteristics of the resultant bio-oil (Titiloye and **Odetoye**, 2013).

Some Biomass Characterisation Methods

The characterization of biomass is a crucial step before its transformation into a useful bioenergy product (**Odetoye** *et al.*, 2020a). This includes physical and chemical methods of proximate and ultimate analyses, thermogravimetric method and structural composition analysis. The resulting information is helpful in the determination of the suitable method, optimal process conditions and the suitability of the biomass for the pyrolysis process (**Odetoye** and Titiloye, 2020).

The composition of various biomass residues is shown in Table 1 below. The composition consists of the percentages of extractives, cellulose, hemicellulose and lignin in the biomass samples. Essentially, lignin is of importance because its content in a biomass is a determinant for the type of catalyst required for a catalytic pyrolysis processes (Pattiya, 2008).

Table 1: Typical compositional analysis results of some biomass residues (**Odetoye** *et al.*, 2014)

Components (%)	Parinari Fruit shell	Jatropha Seed Coat	Jatropha Fruit Shell	Empty fruit bunch	Wheat Straw	Palm shell	Rape Straw	Switch Grass
Extractives	18.1	13.3	42.3	25.5	27.7	6.7	9.7	26.3
Cellulose	45.4	34.0	32.5	23.7	33.2	27.7	37.6	36.0
Hemicellulose	6.4	40.0	10.5	21.6	24.0	21.6	31.4	31.6
Lignin	**30.1**	**12.7**	**5.7**	**29.2**	**15.1**	**44.0**	**21.3**	**6.1**

Ultimate analysis (Table 2) of a biomass sample defines the elemental composition of the biomass. The elements determined in the biomass are carbon, hydrogen, nitrogen, oxygen, sulphur, chlorine and trace elements. A bomb calorimeter is used for the determination of the biomass calorific value, which gives the potential of the sample as a fuel source.

Thermo gravimetric analysis (TGA) is a method used to determine the biomass feedstock’s thermal properties (Figure 1) and to corroborate the proximate analysis results. TGA helps to understand the kinetics and physical properties of a biomass in line with its characteristic composition (Chakravarty *et al.*, 2024). Pyrolysis Gas-Chromatography-Mass Spectrometry serves as a fast method of screening a potential bioenergy feedstock for potential pyrolysis products by subjecting it to the heating rate and process conditions set for the industrial process.

Table 2: Typical ultimate analysis results of jatropha seed coat biomass (**Odetoye** *et al.*, 2018).

Parameters						
	Nigeria	Japan	Indonesia	Indonesia	Thailand**	India
C	48.34	48.15	48.5	50.3	45.5	50.9
H	5.74	6.48	5.7	6.6	7.2	5.8
N	1.17	1.39	0.67	1.8	4	0.8
O*	44.03	-	41.0	38.3	43.3	39.5
S	<0.10	-	0.01	n.d.	-	0.1
Cl	0.62	-	-	-	-	0.1
H/C	0.12	0.13	0.12	0.13	0.16	0.11
HHV(MJ/kg)	20.06	-	-	-	-	16.5

*by difference,
**mixed waste

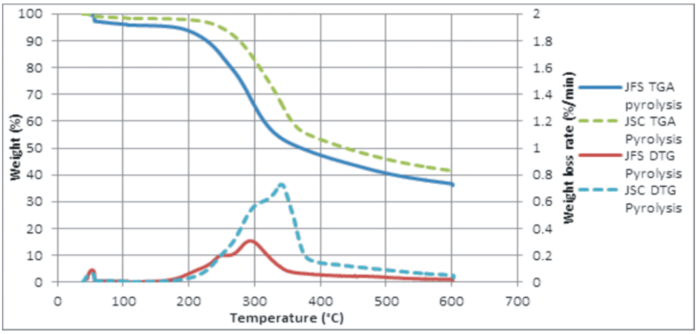


Figure 1: Typical pyrolysis curves for Jatropha fruit shell (JFS) and Jatropha seed coat (**Odetoye** *et al.*, 2018)

Main Biomass Conversion Processes

The choice of method for biofuel production depends on the characteristics of the biomass. Biomasses that are rich in carbohydrates and moisture content are more suitable as substrate for biological conversion methods (Costa *et al.*, 2018). Biomasses with high lignin contents are usually resistant to enzymatic actions. They will need to undergo pre-treatment such delignification, hydrolysis and depolymerisation to make them suitable for biological method (**Odetoye** *et al.*, 2020a).

The three major categories of biomass conversion technologies for biofuel production include the biological, chemical and thermochemical methods:

Biological Methods

Biological methods of biomass conversion include anaerobic digestion and fermentation through the enzymatic action of bacteria and yeast to form fuels such as bioethanol and biomethane. Such products are usually obtained at temperature conditions that are less than 70 ℃. However, a characteristic disadvantage of the biological method is the relatively slow reaction rates which can run into hours and days with low gas yields.

Chemical Method

Another biomass to biofuel conversion method is the chemical method which has mainly been by transesterification route (Ajala *et al.*, 2022). The feedstocks are mainly vegetable oils which are triglycerides of fatty acids. Vegetable oils can be transesterified to ethyl or methyl esters in the presence of ethanol or methanol and hydroxide catalysts. Some of the disadvantages of the transesterification route include the need for methanol recycling and the generation of wastewater which pollutes the environment.

Thermochemical Method

Thermochemical method is the third main biomass-to-biofuel conversion method that is suitable for biomass feedstock with relatively lower moisture contents and high lignin contents. This method is based on heating which is usually associated with chemical reactions that convert biomass feedstock to liquid or gaseous fuels.

Thermochemical techniques consist of liquefaction, combustion, gasification and pyrolysis (Uddin *et al.,* 2018; **Odetoye** *et al.,* 2020).

i. **Liquefaction** is a technique that generates a liquid from the thermal decomposition of solid biomass which can be a direct or hydrothermal process (Gollakota *et al.,* 2018). The liquid produced can further be upgraded for heat and chemical use. Liquefaction is appropriate for processing wet biomass.

ii. **Combustion** has to do with the generation of heat and power from the thermal decomposition of biomass in the presence of excess oxygen. The heat produced cannot be stored hence it is usually utilized instantly for heat or power generation.

iii. **Gasification** involves the conversion of solid biomass to gaseous bioenergy through partial oxidation under very high-temperature condition. A mixture of flue gases produced consists of CO, CH_4, CO_2, H_2 and these gaseous products obtained from the gasification process are of commercial importance in the chemical industry. However, gasification requires intricate equipment and maintenance costs are high **(Odetoye** and Titiloye, 2020).

iv. **Pyrolysis** is an existing and important biomass conversion process that occurs in the absence of oxygen above 400 ^{o}C, (Guedes *et al.,* 2018). It is broadly recognized as a method that attains efficient utilisation of the energy content of biomass compared to other conversion methods. Pyrolysis has been preferred to gasification and hydrothermal liquefaction on the grounds of direct liquid fuel production and relatively less-complicated production equipment. Pyrolysis is thermally applicable to valorisation of wastes into higher calorific value (Guran, 2018). It offers the opportunity for chemicals, fuels and biorefinery (**Odetoye** *et al.,* 2020a).

Biomass Conversion by Pyrolysis Technology

During the pyrolysis process, organic matters are transformed into gases, liquids and solid residues containing carbon and ash. Pyrolysis occurs in two distinct steps, removal of moisture and condensation of volatiles into liquid fraction (**Odetoye** and Titiloye, 2020).

The pyrolytic decomposition of biomass under an inert atmosphere is usually the initial stage of a thermochemical process. This may also be followed by a combustion or gasification process. The main products resulting from biomass pyrolysis are solids, liquids and gases, which vary in proportion to yields and depend on the type of pyrolysis (Guesdes *et al.*, 2018).

Types of Pyrolysis

Pyrolysis is considered predominantly as three types. They are slow, fast and intermediate pyrolysis. The distinguishing factors are largely the temperature, residence time, heating rates and product yields (Titiloye and **Odetoye**, 2013). In slow pyrolysis, the biomass is heated at a moderate temperature between 300 and 400°C where the heating rate is within 0.1 – 1°C per sec and the vapour residence time ranges between 5 and 30 minutes.

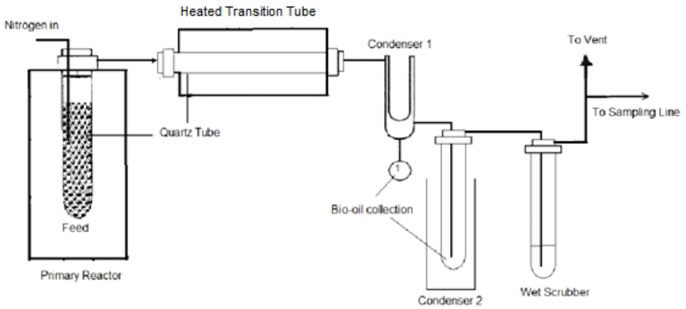


Figure 2: Typical intermediate pyrolysis set up (**Odetoye** *et al.*, 2014)

Intermediate Pyrolysis (Figure 2) is operational within the conditions of the conventional slow and fast pyrolysis procedures with temperature averagely within 450 and 500 °C with controlled residence time and heating rate (Titiloye and **Odetoye**, 2013). Fast pyrolysis has the unique advantage of giving comparatively higher yield of liquid product nearing 79 wt %. It is usually characterised by a faster heating rate of around 500 °C and a shorter residence time of about 2 seconds or less.

Feedstock for Biomass Pyrolysis

In Nigeria, various wastes can serve as feedstock for biofuel production (Titiloye and **Odetoye**, 2013). The choice of biomass feedstock is fundamental to the success and the viability of the pyrolysis process especially in terms of yield. The main organic material sources include agricultural residues, industrial biomass wastes, domestic biomass wastes and sea weeds/algae. Biomass with relatively high ash matter will lead to high char content, and low liquid product yield (**Odetoye** *et al.*, 2020a).

Inorganic constituents in ash such as Ca, K and Na can act as catalysts during the pyrolysis process towards favouring biochar production (**Odetoye** *et a*l., 2013). Lignocellulosic composition, particle sizes, residence time, heating rate and reactor type are important considerations. Process conditions for selected biomass feedstock for pyrolysis are shown in Table3 below:

Table 3: Process conditions for selected biomass feedstock for pyrolysis (**Odetoye** and Titiloye, 2020)

	Rice Husk	Brunei Rice Husk IP	African Moringa	Indian Jatropha	Cassava Rhizome	*Parinari Polyandra* (IP)
Reactor type	Fluidised	Fixed	Fluidised	Fluidised	Fluidised	Fixed
Feed rate g/h	90-150	100	90	90	140	100
Optimum Temperature (°C)	400-450	450	500	500	477	450
Heating rate (°C/min)	-	25	>80	>80	>25	25
Feed particle size (μm)	-	1000	355-849	355-849	355-500	350-800
Holding time (s)	-	-	0.76	0.76	0.74	-
Purge/Fluidising gas	Nitrogen	Nitrogen	Nitrogen	Nitrogen	Nitrogen	Nitrogen
Liquid yield (%)	50	42.17	55.43	52.29	64.9	36.5

IP=Intermediate Pyrolysis

Products of Biomass Pyrolysis and their Applications

Three major products obtainable from the biomass pyrolysis process are pyrolysis oil (which is also known as bio-oil), biochar and gases.

Bio-Oil is a liquid with a deep brownish colour and it contains valuable biochemicals which can serve as the basis for biorefineries. It is CO_2 neutral and reduces nitrogen oxide emissions by over 50% compared to fossil fuels. Bio-oil can be stored and transported as it is the case for petroleum products. It is a renewable fuel that can be used in turbines and typical diesel engines for heat and power generation purposes especially when upgraded.

Bio-oil does not spread over water in thin layers like petroleum, resulting in environmental pollution (Bridgwater and Peacock, 2000). Other chemicals that can be obtained from pyrolysis oil include food flavourings, resins, agro-chemicals, fertilizers and emissions control agents. (Conti *et al.*, 2017).

Biochar is a fine-grained, highly porous nature solid pyrolysis product which is about 65-76 wt % carbon 5-12% ash, and less than 2% moisture. It has a heating value of around 28-30 GJ/tonne and it can be burned for energy. Char consists mainly of carbon and hydrogen. It exhibits catalytic activity at the secondary cracking in the vapour phase. (Bridgwater and Peacock, 2000). Biochar has also been considered as a means of tackling the global warming problem by utilizing it for carbon sequestration (**Odetoye** *et al.*, 2020a).

Gases mainly produced during the pyrolysis process are non-condensable consisting mainly of carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2), methane (CH_4), and other hydrocarbons (short –chained alkanes and olefins). These gases are valued as biosyngas which is quite similar to syngas (a mixture of H_2 and CO) after cleaning. Biosyngas (predominantly a mixture of CO and H_2) are obtained from biomass as a by-product of pyrolysis or by gasification. The gas is then cleaned and converted to hydrocarbons of variable chain length using a gas-to-liquid technology involving the Fischer-Tropsch process to produce diesel (Doss and Bridgwater, 2010).

Biomass Pyrolysis Reactors

An extensive variety of reactor types and configurations have been developed with different approaches for fast pyrolysis technology (Bridgwater, 2012). However, there are challenges encountered in maximising the liquid product yield in pyrolysis. This is attributed to unsuitable pyrolysis reactor configurations and process conditions. Fluidized bed reactors have been widely researched (Suntivarakorn*et al*., 2018) and are the most generally accepted type of reactor for fast pyrolysis. A fluidised bed reactor also provides an efficient way of quick separation of char from the pyrolysis vapours and ensures the char is not retained in the reactor bed. However, one major drawback of the fluidized bed reactors is the unavoidable escape of the char into the bio-oil thereby reducing the oil stability and encouraging polymerisation of the product leading to more viscous oil. Figure 3 and Table 4 show typical characteristics of fast pyrolysis reactor types.

Table 4: Some fast pyrolysis reactor types (Bridgwater *et. al*., 2000)

Reactor type	**Characteristics**
Fluidised bed	Heated recycle gas. High rates of heat transfer, efficient mixing, smaller particle size of less than 2 mm, partial gasification
Ablative	Reactor wall heating. Large particle size, around 5 mm, High char abrasion, sophisticated reactor
Circulating Fluidised bed	In-bed gasification of char to heat sand. Relatively high rates of heat transfer, high char abrasion, solid recycle, complex design
Entrained Flow	Minimal heat transfer rates, particle size of less than 2 mm, limited gas-solid mixing.
Rotating cone	Wall and Sand Heating
Transported bed	Re-circulated hot gas heated by char combustion
Vacuum moving bed	Direct contact with the hot surface

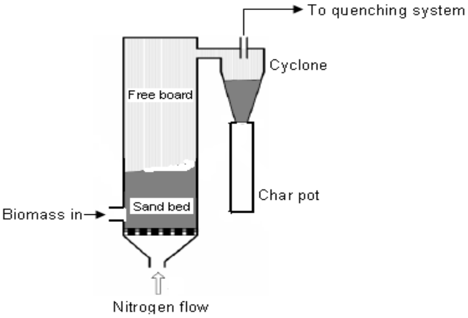


Figure 3: Schematic diagram of a fluidized bed reactor

My Modest Contributions to Biomass, Bioenergy and Bioproducts

Mr. Vice-Chancellor, please permit me to share some of my modest contributions to biomass and bioenergy research.

Biofuel Policy and Implementation in Nigeria

Biofuel policy is the expression of the political will of the government in regulating the adoption of biofuel. The document is usually a guide for would-be investors in the industry. The biofuel production industry is still in the underdeveloped phase in Nigeria, although the policy has been drafted since 2007 with the incentive of tax holiday for would-be investors. I had made presentations at professional engineering conferences on the review of the Nigerian biofuel policy and on the level of biofuel research in Nigeria at UNESCO organised conference to which I was invited (**Odetoye** *et al*., 2019a).

From the Official Gazette of the Nigerian Biofuel Policy and incentives reviewed in 2010; millet, sorghum, sugar and jatropha (*lapalapa*) were the biomass feed stocks gazetted for biofuel production in Nigeria (NNPC, 2010). However, apart from jatropha, the rest of the feedstocks are first-generation which undesirably competes with food sources. It has been recommended (**Odetoye** *et al*., 2019b) that the Nigerian biofuel policy must be subjected to another review to accommodate other locally available third-generation biomass feedstocks and other biofuels apart from food sources (such as cassava) based bioethanol.

Currently, biofuel policy is yet to be implemented in Nigeria though the bill has passed the second reading stage at the National Assembly (Odekina, 2023). The key actors on the implementation platform were identified as the government, investors, researchers and research institution leaders, farmers, traditional land owners, the youth, and media, who are to play their parts in the symphonic melody of biofuel policy implementation (**Odetoye** *et al*., 2019a).

Biomass Feedstock

In the search for suitable Nigerian biomass that will not compete with food sources, we investigated various samples of biomass residues for biofuel production. These include African oil bean seed husk (**Odetoye** and Ocheni, 2022), jatropha seed coat, jatropha fruit shell (**Odetoye** *et al*., 2018a; **Odetoye** *et al*., 2018b.), jatropha seed cake, rice husk (Abubakar *et al*., 2012 and Aladetuyi *et al*.,2016), parinari shell (**Odetoye** *et al*., 2013), egg shell (**Odetoye** *et al*., 2021), waste chicken fat (**Odetoye** *et al*., 2019), waste cooking oil, cocoa pod (**Odetoye** *et al*., 2019) locust bean pod, corn cob, groundnut shell, *Prosopis africana* pod, among others.

African Oil Bean

Biomass residue from African oil bean, *Pentaclethra macrophyla* Benth (*ugba*) seed husk (Figure 4) was characterised for potential application as feedstock for the production of bio-oil via pyrolysis. The proximate analysis (Table 5) shows low ash content (0.7 %) and volatile content of 76.2% of the husk is favorable to high bio-oil yield, while the TGA analysis result indicated that only 19.5 % of the weight was left at a temperature of 457˚C. The ultimate analysis revealed relatively high carbon content (47.65 %), desirable heating value (19.5 MJ/kg), low nitrogen (<1 %) and sulphur (< 0.1) contents. The cellulose, hemicellulose, lignin and extractive contents were determined as 42.34, 19.2, 14.47 and 23.99 % respectively. Hence, we reported for the first time that African oil bean seed husk was found suitable for bio-oil production (**Odetoye** and Ocheni, 2022) and the bio-oil was eventually produced.

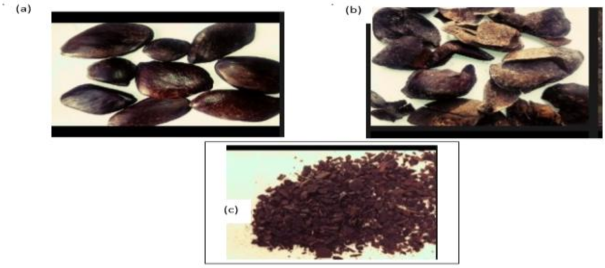


Figure 4: African oil bean; (a) seed (b) husk and (c) pulverized husk (**Odetoye** and Ocheni, 2022)

Table 5: Proximate, structural, ultimate analysis and higher heating values of African oil bean residue.

Proximate analysis %		**Structural analysis %**	
Moisture content	9.89±0.012	Hemicellulose	19.2±0.06
Ash content	0.71±0.0667	Cellulose	42.34±0.05
Volatile content	76.2±0.00	Lignin	14.47±0.02
Fixed carbon	13.23±0.58	Extractives	23.99± 0.01
Ultimate analysis %			
C	47.65±0.029		
H	5.84±0.12		
N	1±0.33		
S	0.0967±0.00		
O	45.4±0.06		
Higher heating value			
Bomb calorimeter value	19.5 MJ/kg		

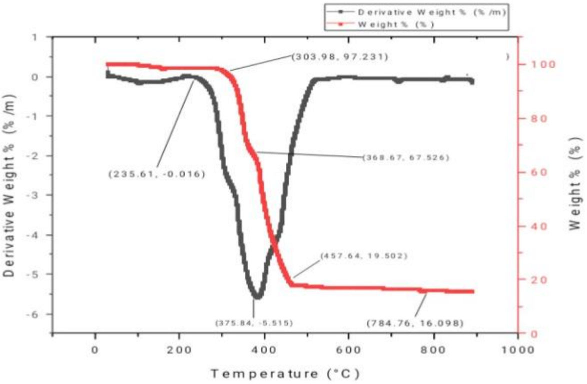


Figure 5: TGA analysis of African oil bean (**Odetoye** and Ocheni; 2022)

Parinari Fruit Shell Biofuel

Parinari polyandra Benth fruit is another potential source of biomass feedstock that has not received enough attention (**Odetoye** and Udoh, 2022). The seed oil has been recommended as a replacement for linseed oil in the alkyds and paints production (**Odetoye** *et al.*, 2008 and **Odetoye** *et al.*, 2013) for bio-oil production and biorefinery. However, the shells constitute a considerable waste generated during the process of oil extraction from the fruit. We, therefore, attempted the development of the oil extraction process with the valorization of the residue for biofuel production.

In a collaborative effort, the work on thermochemical characterisation of *Parinari polyandra* Benth fruit shell, as a renewable energy feedstock was reported (Titiloye *et al*., 2013). The thermochemical characteristics were evaluated. The biomass was found to have potential use in bio-oil production. The inorganic contents were relatively low and K was found to be the most abundant inorganic element. The ash content was found to be within acceptable limits. The TGA and DTG profiles indicated that the waste fruit shells were viable for pyrolysis reaction.

Vice-Chancellor, sir, we reported for the first time the production of bio-oil from *Parinari polyandra* Benth fruit shell (**Odetoye** *et al*., 2014 and **Odetoye** *et al.,* 2020). The bio-oil (Figure 6) was successfully produced on a fixed – bed reactor using an intermediate pyrolysis process within a temperature range of 375 – 550 ℃. The properties of the bio-oil obtained were found comparable with those of other bio-oils reported in the literature. The presence of valuable compounds such as phenolic compounds in the bio-oil indicated potential for industrial applications. The most abundant organic compounds present were acetic acid, toluene, 2-cyclopenten-1-one, 2-furanmethanol, phenol, guaiacol and 2,6-dimethoxyphenol. The bio-oil produced at 550°C gave a higher quantity of more desirable compounds.

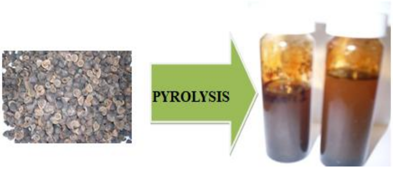


Figure 6: Parinari fruit shell bio-oil (**Odetoye** *et al.,* 2014)

Jatropha Fruit Waste Bio-Oil

The thermochemical properties of the jatropha (*lapalapa*) biomass residues of Nigerian origin were also investigated towards bio-oil production (**Odetoye** *et al.,* 2018). The biomass residues (*Jatropha curcas* fruit shells and seed coat) were obtained from their mature jatropha fruits and subjected to physico-chemical characterisation (structural composition analysis, thermogravimetric analysis, proximate and ultimate analyses). The structural compositions (extractives, hemicellulose, cellulose and lignin contents) of jatropha fruit shell and jatropha seed coat were (3%, 34.0%, 40.0%, 12.7%) and (42.3%, 32.5%, 10.5%, 5.7%), respectively. The thermogravimetric analysis showed that the ash contents of the jatropha seed coat and jatropha fruit shell were 0.8% and 15.4%, respectively. The carbon contents were 48.3% and 41.5% while measured calorific values were 20.06 MJ/kg and 17.14 MJ/kg for jatropha seed coat and fruit shell, respectively. The carbon, hydrogen, nitrogen and sulphur contents of the residues were found suitable for bio-oil (Figure 7) production (**Odetoye** *et al.,* 2018).

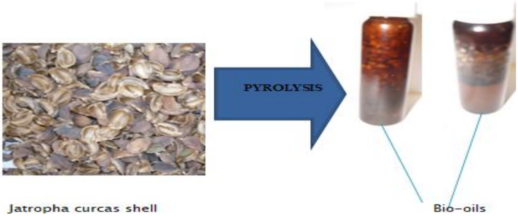


Figure 7: Jatropha shell pyrolysis oils (**Odetoye** *et al.,* 2018)

In another work, catalytic pyrolysis of some agricultural wastes such as jatropha press cakes and rice husk, was carried out on an intermediate pyrolysis rig (Figure 8). The presence of the catalyst (zeolite ZSM-5) in the secondary reactor influenced the bio-oil properties positively by reducing the acetic acid contents and nitrogen-containing compounds produced when parinari fruit shell, jatropha press cakes and rice husk were investigated (Abubarkar *et al.,* 2012).

The intermediate pyrolysis rig is shown in Figure 8 below.

1 = primary reactor, 2 = secondary reactor , 3 = dry ice condenser , 4 = oil pot 1, 5 = secondary condenser, 6 = scrubber

Figure 8: Experimental set up for intermediate pyrolysis experiment (**Odetoye** *et al.,* 2018)

My Contributions to Biobased Catalysts and Biodiesel Feedstock

Biodiesel feedstock and Biobased catalysts

Biodiesel has been considered as one of the sustainable fuel alternatives. However, the higher production cost of biodiesel compared to the fossil fuel counterpart is one of the major drawbacks of biodiesel production (**Odetoye** *et al.*, 2021). The relatively higher cost is attributed to the raw materials mainly vegetable oil (75%) and alcohol with 12.6% on catalyst materials (Ajala *et al.,* 2020).

Mr. Vice-Chancellor, we attempted to make biodiesel compete economically with fossil fuel by utilising non-conventional oils as feedstock and cheaper agro-waste ashes from the cocoa pod and rice husk as transesterification catalyst instead of employing the conventional alkaline catalysts such as KOH and NaOH (Aladetuyi *et al.,* 2014; Amos, **Odetoye** *et al.,* 2016 and Motojesi *et al.,* 2017).

Various non-conventional seed oils have been investigated for the production of biodiesel and they were found suitable as biodiesel feedstock. The biodiesel samples produced have been reported to meet the ASTM standards. These include parinari seed oil (Amos *et al.*, 2016; Bulus and **Odetoye**, 2022 and Bakare, 2023), tobacco seed oil (Motojesi *et al.,* 2017), palm kernel oil (Aladetuyi *et al.,* 2014; Ajala *et al.,* 2019, 2020, and 2022), almond oil (Adeniyi *et al.,* 2019), waste cooking oil (Enitan, 2023). Similarly, some agricultural residues have been investigated as bio-based catalysts for transesterification processes (Figure 9).

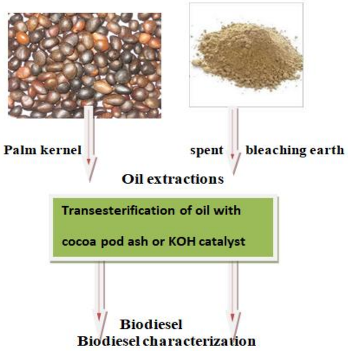


Figure 9: Biodiesel production from palm kernel oil and oil obtained from spent bleaching earth with cocoa pod ash catalyst (Aladetuyi *et al.*, 2014)

Cocoa pod ash-based catalyst was found to produce neater biodiesel compared to the rice husk ash-based catalyst. Therefore, cocoa pod ash (with a relatively high content of potassium) was found more suitable as a direct substitute for conventional KOH catalyst in the industrial production of neat biodiesel (Motojesi *et al.*, 2017).

Biodiesel Production from Poultry Wastes

Vice-Chancellor, sir, we investigated the transesterification of oil from chicken slaughter waste fat while adopting a cheap, non-solvent process for extraction (**Odetoye** *et al.*, 2021). Biodiesel was successfully produced using chicken eggshell-derived heterogeneous catalyst (Figures 10 and 11). The transesterification experiment was based on a two-factor, three-level central composite design while catalyst concentration and reaction time were considered as the factors which had significant effects on the yield of the biodiesel. A maximum yield of 90.2% biodiesel was obtained at 2 % catalyst weight and 2 hour reaction time (**Odetoye** *et al.*, 2021). The yield showed that egg shell waste is a potential affordable catalyst source for biodiesel production from waste chicken fat feedstock. Utilisation of these wastes can add value to the poultry production process and minimise the wastes in the poultry industry.

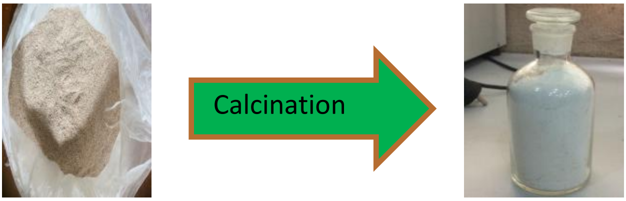


Figure10: Processing of ground egg shell to calcinated egg shell

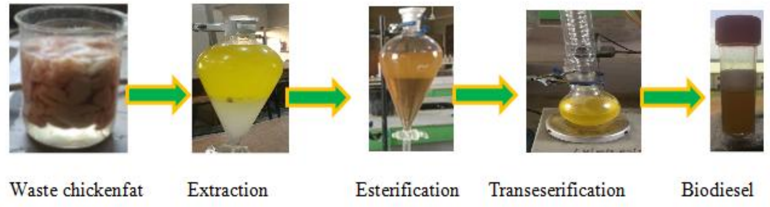
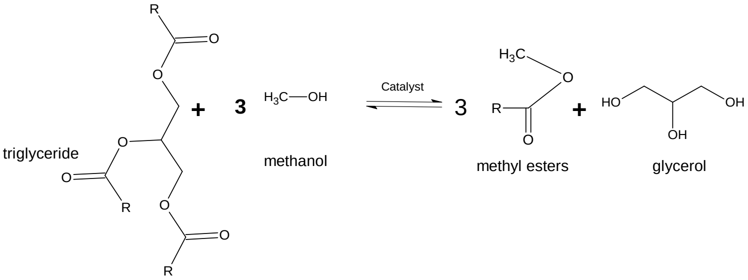


Figure 11: Biofuel production from waste chicken fat and egg shell (**Odetoye** *et al*., 2021)

In another work, **Odetoye** and Amusan (2019) investigated the use of cocoa pod ash as the catalyst for biodiesel production from waste chicken fat. The results indicated that 3 wt % catalyst concentration and 2 hours reaction time yielded 75.4% of biodiesel/methyl esters (Scheme 1) from chicken fat.



Scheme 1: Production of Fatty Acid Methyl Esters (**Odetoye** and Amusan, 2019)

Biodiesel from Non-Conventional Oils

More recently, Ogundipe and **Odetoye** (2023) evaluated the suitability of the seed oil of *Mucuna pruirien* (Figure 12) locally known as “werepe” for biodiesel production. The oil extraction process was optimized based on Central Composite Design enhanced response surface methodology (Figure 13). An optimum biodiesel yield of 94.6% was obtained and the biodiesel properties fell within the ASTM D6751 standards specifications for engine fuel. We also investigated the optimisation of biodiesel production from the avocado plant **(***Persea americana***) and** an empirical correlation was developed to predict the biodiesel yield of the **avocado plant** (Adeniyi *et al.*, 2019b)**.**

Figure 12: *Mucuna pruirien* pods and seeds(Ogundipe and **Odetoye**, 2023)

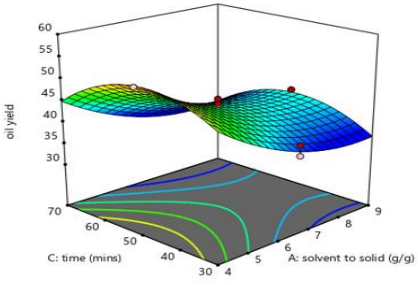


Figure 13: Response of oil yield with time and solvent-to-solid ratio for *Mucuna pruirens* seed oil extraction process (Ogundipe and **Odetoye,** 2023)

Other Contributions to Sustainable Product Development

In the search for sustainable biomass feedstock that will not compete with food sources various samples of biomass were investigated for other bio-based products. The products include alkyd resins (**Odetoye** *et al*., 2012; **Odetoye** *et al*., 2013 and **Odetoye** *et al*., 2019; Awolola *et al*., 2023 and **Odetoye** *et al*., 2024); metallic soap (Amos, *et al*., 2021), almond oil based metal carboxylates in a collaborative work (Amos, *et al*., 2022), biolubricants (Bulus and **Odetoy**e, 2022).

Biocomposites were also produced (Odiase and **Odetoye**, 2022; **Odetoye** and Arowojobe, 2021; **Odetoye** and Akande, 2020; **Odetoye** *et al*., 2022 and Yusuf *et al.,* 2024) from flamboyant tree pods, (Otaru, 2023) parinari shell (**Odetoye** and Ashaolu, 2020), palm kernel shell, *Prosopis africana* using waste LDPE (“pure water” sachet) as matrix and recommended for indoor applications.

Development of some Pilot Plants and Rigs for the Production of Biobased Materials

Vice-Chancellor, sir, I have been able to contribute to the development of some pilot plants and rigs for the production of bio-based materials A dual-function mobile biodiesel and biolubricant production pilot plant (Figure 14a) was developed. This was exhibited at the Nigerian Universities Research and Development Fair (NURESDEF 2016) Exhibition in Awka, Enugu State. A pyrolysis rig (Figure 14b) was also developed for the pyrolysis of waste biomasses and plastics wastes towards waste valorisations. We have been working on value creation for waste plastics (Odiase and Odetoye, 2022) and the valorisation of agricultural residues (**Odetoye** and Ocheni, 2022).

The mobile biodiesel and biolubricant production pilot plant and pyrolysis rig are shown in Figure 14 below.

(a) (b)

Figure 14: (a) Design and fabrication of mobile biodiesel and biolubricant pilot plant and (b) Pyrolysis rig

Melt-mixer (Figure 15) was developed for the valorisation of waste pure water sachet, low-density polyethylene (LDPE) and biomass residues into biocomposites. Heating and mixing were successfully done with a designed and fabricated melt mixer, waste LDPE and *Parinari* shells were successfully converted to a potential value-added product (Odiase and **Odetoye**, 2022). Effects of selected factors (filler size and filler loading to matrix weight ratio) were investigated on produced biocomposite samples where the optimum value of tensile strength of produced biocomposite was obtained at 10% filler to matrix loading with particle size 0.42 mm which produced a Young's modulus of 320.3 N/mm^2.

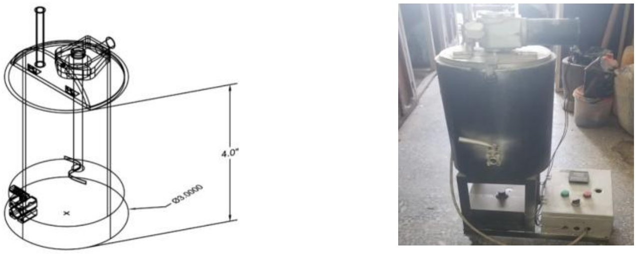


Figure 15: Wireframe AutoCAD design view and fabricated melt -mixer (Odiase and **Odetoye,** 2022)

Contributions on Seed Oil Based Alkyd Resin Production

Alkyd Resin is an indispensable raw material in the paint industry. We investigated and recommended some conventional tropical seed oil and found them suitable for alkyd resin production. There was a need to produce alkyds from our locally available materials to conserve our foreign exchange. Currently, in the Nigerian paints industries, alkyds are obtained mainly by importation since conventional vegetable oils for making alkyds are not available (Awolola *et al*., 2023; **Odetoye** *et al*., 2024).

Vice-Chancellor, sir, we have investigated the production of alkyds from non-edible oils such as tobacco seed oil (Ogunniyi and **Odetoye**., 2008), jatropha seed oil (**Odetoye** *et al.,* 2013), black sesame seed oil (Awolola *et al., 2023*). Pathways to improve the drying properties of *Jatropha curcas* Linnaeus (JCL) alkyd resins were reported for the first time (**Odetoye** *et al*., 2012). The study indicated that the desaturation of JCL oil before the preparation of its alkyds slightly improved the initial drying times of the resultant alkyds.

Parinari polyandra Benth seed oil was investigated and found suitable for alkyd resin production (**Odetoye** *et al*., 2013). Four types of alkyd resin were prepared using 35%, 50%, 60%, and 75% oil formulations of parinari seed oil in a two-stage alcoholysis-polyesterification method. The drying properties of the alkyds were found to compare favourably and competitively with those of the commercial standards. Parinari oil alkyds were found to be generally more viscous and faster drying. The study indicated that *Parinari polyandra* Benth seed oil was a potential renewable, nonedible, raw material for the coatings and paints industry in Nigeria. This work was in response to a search for locally available seed oil to replace linseed oil-based alkyd which is a foreign raw material used in the Nigerian Paints industry. However, that paint company which consulted my mentor and Ph.D. Supervisor did not eventually sponsor the research or follow up due to the “Nigerian factor”.

Biobased Product Development from Parinari

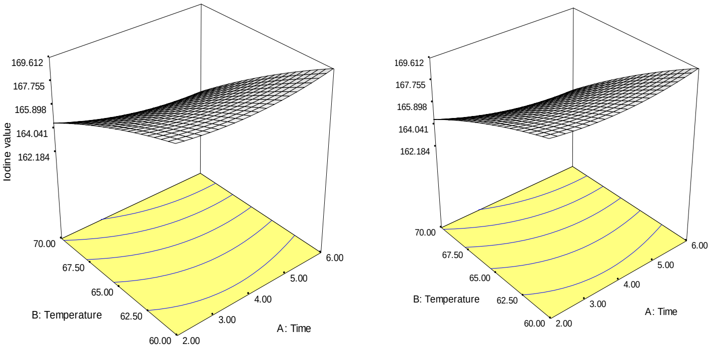
The suitability of parinari oil as a bio-based feedstock was reported by **Odetoye** and Udoh, 2022). *Parinari polyandra* Benth (Figure 16) is a tropical plant that is available in Nigeria and other parts of West Africa. Some of its local names are: ***Aboidefin* or *Abere*** (**Yoruba)** and ***Gwanjan kusa*** **(Hausa)** (Bello and Lajide, 2011). Although, the parinari plant is yet to be fully studied and harnessed industrially. Our research efforts were directed towards the utilization of parinari for industrial product development and energy applications (**Odetoye** and Udoh, 2022). We have reported the optimal extraction process parameters of the parinari oil (**Odetoye** *et al.,* 2016). Parinari oil is a non-edible drying oil due to its fairly high level of unsaturation (**Odetoye** *et al.*, 2013), a property that gives it a high potential for the production of bio-based products. The seeds gave an optimal oil yield of 64%. However, the process of obtaining the kernel is laborious and the parinari shell waste generated during the process is substantial. Hence, the valorisation of shell waste was investigated.

Figure 16: The parinari fruits on its tree (**Odetoye** *et al.*, 2013)

In another study, the extraction process of parinari seed oil was carried out by Afolabi *et al.* (2015). Extraction process parameters were found to influence the quality of oil obtained from seeds during the extraction process (Figure 17). The effect of extraction process parameters (Table 5) on the quality of parinari seed oil was investigated **(Odetoye** *et al.,* 2016).

Table 5: Optimum values for the Parinari oil extraction process (**Odetoye** *et al.*, 2016)

Process parameters	Optimum values
Time (hr) A	2
Temperature (^{o}C) B	60
Solid/solvent ratio(g/ml) C	0.07
Solvent type D	n-Hexane
Oil yield (%)	54.04
Acid value (mg KOH/g oil)	2.45
Iodine value (mg I_2/g oil)	169.2
Saponification value (mg KOH/g oil)	246.1
Desirability	0.87



A B

Figure 17: Effect of temperature and time on iodine value for n-n-hexane and petroleum ethersolvent types (**Odetoye** *et al.*, 2016)

Parinari oil has a relatively high iodine value and the oil can be conveniently classified as a drying oil comparable with linseed oil. High iodine value and refractive index are indicative of high level of unsaturation in oil. Drying oils are raw materials for the oleochemical industry. The optimisation was achieved based on economic considerations since reduced temperature and time correspond to reduced operating costs of the extraction process and the desirable oil characteristics (Odetoye *et al.*, 2016).

Process Design

I have been involved as the Process Design team leader, from the inception of the Department, in the supervision of students process plant design projects until I went on a sabbatical leave in 2017. I am still part of the team and have been able to supervise process plant designs for over one hundred (100) students. The current project is on the design of a process plant to produce fuel from waste plastic bags.

Future Plans and Research Outlook

I intend to expand my research horizon in the area of waste-to-energy towards:

a. the development of co-pyrolysis pilot plants for the valorisation of mixed agricultural residues, waste plastics, hospital wastes and municipal solid wastes in Nigeria;
b. the valorisation of more Nigerian agricultural residues/wastes for biofuel and bioproducts production;
c. more work on modelling, simulation and optimization of bioenergy production processes targeting various domestic wastes by biochemical, chemical and thermochemical methods for circular economy and
d. thermochemical conversion of plastic wastes for electricity generation and other collaborative research works.

Community Services

University Community

Vice-Chancellor, sir, my modest contributions include serving in various capacities in the Departmental, Faculty and University boards and committees. As the pioneer-level adviser for the Department, I was able to successfully mentor the first (and another) set of chemical engineering students from admission to graduation. I served as the Ag. Head of the Department from 2018 to 2020, when the department faced both the NUC and COREN accreditations successfully. With the assistance of the host, Dr. Omotayo Titiloye, I facilitated the Unilorin-Swansea University, United Kingdom MOU for 2019-2022.

Examiner and Reviewer

I was privileged to serve as an editorial board member, proctor and reviewer to various reputable Scopus-indexed journals (NJTD, Elsevier, others) and engineering professional bodies both locally and internationally, including the American Society of Engineering Management (ASEM). I also served as an External Examiner in Universities within and outside Nigeria, including, the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, South Africa.

Professional Bodies and others

I have served in various capacities with engineering professional and regulatory bodies, and other communities. These include:

i. Service as the pioneer Chairperson (1992 set) of Ilorin Grammar School Old Students Association. As the former head girl, I was able to garner the support of my old classmates to rebuild some dilapidated classrooms and administrative block of my alma mater in 2019;

ii. It has been my passion to encourage younger females in the field of science, technology and innovation, to take up the engineering profession, to close up the gender divide in technology. I served as the pioneer executive member and later as the 5th Chairman of the Association of Professional Women Engineers of Nigeria (APWEN), Ilorin Chapter in 2012;

iii. I have been able to impact my community, serving as a role model to the younger generation, engineering, academic community (and others) in Nigeria and internationally and I have received, by the grace of God, more than 26 awards;

iv. I have been involved in catch-them-young programmes for the engineering profession and served as part of the organisers of the Nigerian Society for Engineers Essay Competition for Nigerian University Students, NSE career talks to secondary schools, APWEN career talks to girls in villages, organized Engineering Graduate induction ceremony for various universities including KWASU, Malete, Unilorin and Landmark Universities, Omu-Aran, Kwara State.

Figure 18: The NSE Branch Engineering Centre, Tanke, Ilorin

v. I have been privileged to serve as an executive member, and council member of NSE at the Branch and National levels (Financial Secretary, Treasurer, General Secretary and Vice-Chairman). In 2020, I was elected as the 21st Chairman of the Nigerian Society of Engineers, Ilorin Branch as the first female to assume the office in 52 years. I was able to garner support and contributed to the development of the Branch in outstanding ways including growth in professional and welfare activities. By the grace of God, the Branch Engineering Center at Tanke was completed and commissioned. I am still serving as an Ex-Officio member. I also contributed as a committee member towards the kick-starting of the NSE Omu-Aran Branch during my sabbatical days at Landmark University, Omu-Aran.

vi. I rendered services in various capacities at the Council for the Regulation of Engineering in Nigeria (COREN) in the following capacities:
   a. Accreditation resource person to Universities in Bauchi, Enugu and Port-Harcourt;
   b. COREN Team member that administered Professional Interviews to Expatriates at Chevron in Lagos;
   c. Member of the Engineering Practitioners' Examination Committee of COREN since 2023;

vii. Sub-Committee Chairman for National Conference and AGM of Nigerian Society of Chemical Engineers (NSChE) in 2022 and Technical Committee Member, Oyo-Osun-Kwara-Ekiti NSChE Chapter and

viii. I have been privileged to serve as the Kwara Conference Youth Director (2017-2020) and Kwara Conference Children Ministries Director (2016-2020) of the Seventh-day Adventist Church in Kwara State (**Odetoye**, 2017 and **Odetoye** 2019). I served as Choir leader at the church and District levels and I am still serving as a choir member in my local church and as the Matron of the Adventist Students Fellowship, Unilorin.

International Linkages

I have served as a visiting Researcher at Aston University, Birmingham, United Kingdom sponsored by the European Bioenergy Research Institute (now Energy and Bioproduct Research Institute) /School of Engineering and Applied Sciences. I was privileged to obtain another Postdoctoral Award through L'Oreal UNESCO for Women in Science, Sub-Sahara Africa at Johannesburg, South Africa, in 2014 and Alternate award from the American Association of University

Women (AAUW) in 2011. I was privileged to represent Nigeria at the Gender in Science, Engineering, Technology and Innovation (GenderInSITE) workshop held in Harare, Zimbabwe organised by UNESCO-ANSTI in 2015.

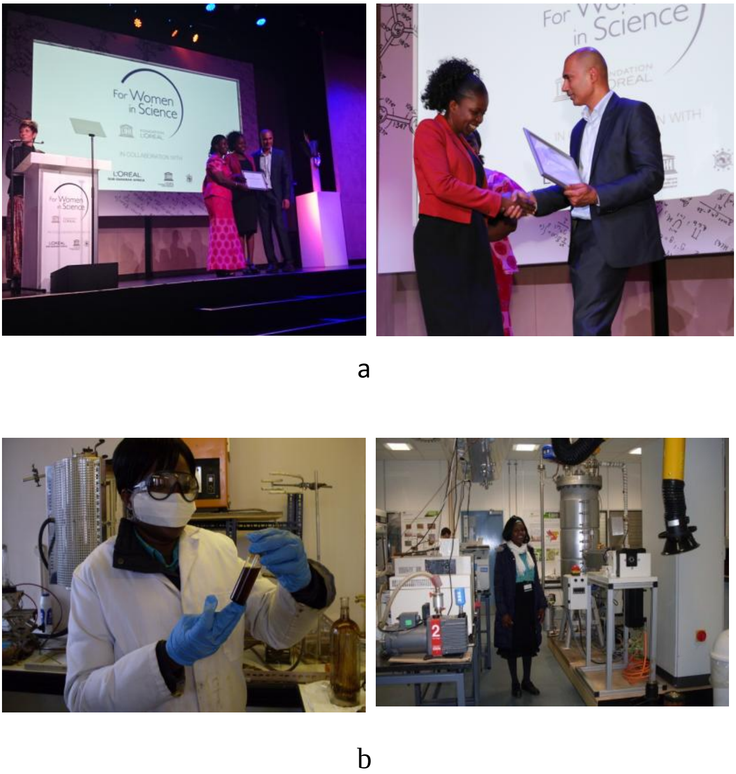


Figure 19: (a) L’Oreal-UNESCO for Women in Science, Sub-Saharan Africa Fellowship, South Africa (b) Visiting Scholar Award, Chemical Engineering and Applied Chemistry Department, Birmingham, U.K.

Conclusion

Mr. Vice-Chancellor, in the course of this lecture, I have been able to highlight the significance of biomass to bioenergy and the conversion methods, biomass thermochemical characterization methods, the importance of pyrolysis as a biomass conversion process, products of biomass pyrolysis, my modest contributions on biomass waste characterisation, biomass waste pyrolysis, bioenergy and some bioproducts production towards symphonic sustainability.

There is a need to be intentional about harnessing the abundant biomass endowment of Nigeria and other sub-Saharan African countries by developing home–grown technologies for the conversion of such biomass to bioenergy. Waste biomass pyrolysis should be considered as a potential alternative biofuel production technology that can be a complementary effort to other existing biomass conversion technologies in Nigeria. It is a potentially beneficial route to biofuel with attending benefits for waste reduction, wealth creation and greenhouse gases (GHGs) minimisation and being non-competing with food sources. It is a promising means of meeting the global energy challenge that should be explored and funded in Nigeria. In a larger context, Nigeria being the giant of Africa should take the leading step in adopting biomass waste - to - energy technologies for producing carbon-neutral fuels and bioproducts, as part of an overall effort to reduce greenhouse-gas emissions that contribute to climate change.

Recommendations

Mr. Vice-Chancellor, based on my research activities, I want to make the following recommendations:

i. The Federal Government should be more intentional about developing a home-grown technology-driven economy in Nigeria in every facet, specifically in the areas of biofuel production and waste management. With the very high turnout of biomass residues and solid wastes generated daily in Nigeria, the potentials for biofuel production as a complementary effort should be harnessed through the adoption of pyrolysis pilot plants, scale-up and commercialisation;

ii. there is a need to standardise our waste management methods to include sorting from source to prepare feedstock for valorisation through pyrolysis. The waste management team should work hand-in-hand with researchers to incorporate pyrolysis as part of the waste treatment technique which will involve the formulation of relevant policies including sorting of biomass and other wastes from the source;

iii. biomass waste pyrolysis is a potential means of converting our wastes to wealth and creating waste-collecting jobs for people and opportunities for skilled engineers and technicians, with the potential advantage of making our environment a cleaner place to live in. Bush burning which is a source of greenhouse gases (GHGs), will also be minimised when dried grass has economic value through pyrolysis. The Government as well as private investors should work in partnership with researchers and take bold steps towards this area;

iv. the current Biofuel policy should be reviewed to suit the Nigerian environment and situation. The Government is to exercise strong political will in driving the biofuel policy implementation. Co-ordination of other stakeholders lies mainly on the government. Aggressive pursuance of the actualisation of biofuel development is needed on the side of the government;

v. dedicated government agencies such as the Biofuel Energy Commission under the Ministry of Energy, are to be put in place to monitor the implementation of the biofuel policy from time to time and carry out necessary reviews as implementation progresses. The focus can be shifted from food as biofuel feedstock to turning waste into energy in biofuel policies;

vi. the Government should establish centers of excellence where pyrolysis and other biofuel technologies will be taken as the research focus towards developing our biofuel technology that will be suitable and sustainable with our local materials, which can be developed by us Nigerian Academia and Engineers;

vii. the researchers should be sensitised towards proactive research for more realistic methods and utilisation of locally available feedstock for biofuel production, while the government should be ready to facilitate the funding of biofuel research to develop home-grown technology to encourage indigenous production of biofuel; and

viii. collaborative linkages among the academia, industry and policy makers should be strengthened for an effective technology-driven economy in Nigeria.

Acknowledgements

Vice-Chancellor sir, by the grace of God, I am a product of the joint efforts of many wonderful people and organisations. Consequently, I thank the Vice-Chancellor Prof. Wahab Olasupo Egbewole, SAN and the immediate past Vice-Chancellor, Prof. Sulyman Age Abdulkareem, FNSChE, current and past Principal Officers at this inaugural lecture. I appreciate the Library and Publications committee under the able leadership of Prof. A.A. Adeoye for reviewing the manuscript, even at “odd” times. Thank you for your sacrifice. Special thanks to the Registrar, Deputy Registrar (Senate) and everyone who has contributed in one way or the other to the success of today’s inaugural lecture. I appreciate all physical and virtual attendees today, thank you all for being here. I would have loved to list everyone who has contributed in one way or the other to the symphony of my career life but I am constrained by time and space. If there is anyone or group inadvertently left out, please, accept my unreserved apology.

I am grateful to God for my parents Pa and Madam Samuel Olayiwola Obala, my first teachers. Thank you for your love, care and encouragement. Your small girl is now a Professor. I especially thank my Mum, Deaconess Victoria Oluyinka Obala who believed in what a girl-child can deliver! Mummy, thank you for your persistent care, prayers, sacrifices and support all the way and for believing in me! I am so grateful to God who has made it possible for you to be called “Mama Prof.” in your lifetime. Thank you for being here despite your recent life-threatening challenge.

I acknowledge my Uncle and Aunt, Elder Prof. David Oladimeji Alao (Chief of Staff, Babcock University) and Dr. Mrs. Esther Monisola Alao, you are more than a parent figure. I appreciate everything you have contributed to making my life today. Thank you for your care and training over my life and for your immeasurable contributions to my life. I also appreciate all my Aunts/Uncles in Atolagbe family (including Engr. Abiodun Atolagbe) and the entire Alao family. Ayo Alao, Fisayo Ogunwemimo, Bisi Ogunyemi, Juwon Alao and family, you have been wonderful.

I appreciate my siblings for their love and support all through, over the years. Mr. and Mrs. Toyin Abdulazeez, Mr. and Mrs. Bunmi Abidakun, Engr. and Mrs. Tayo Adesanya and Mr. and Mrs. Emmanuel Ajibola. Thank you for your support.

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1. O Lord my God, when I in awesome wonder
Consider all the worlds Thy hands have made
I see the stars, I hear the rolling thunder
Thy power throughout the universe displayed

Refrain

Then sings my soul, my Savior God to thee
How great thou art, how great thou art
Then sings my soul my Savior God to thee
How great thou art, how great thou art!

2. And when I think, how God, His Son not sparing
Sent Him to die, I scarce can take it in
That on the cross, my burden gladly bearing
He bled and died to take away my sin

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References

AbuBakar M.S., Titiloye J.O. & **Odetoye T. E., (2012)**. Catalytic pyrolysis of rice husk, Jatropha and *Parinari Polyandra* with ZSM-5, ***Proceedings of International Energy Conference, Sustainable Future Energy**2012* ***and 10th SEE Forum Innovations for Sustainable and Secure Energy,*** J.T. Link (ed), 234-241. Published by Universiti Brunei Darussalam. Available online at http://fos.ubd.edu.bn/energy2012/ data/_uploaded/file/Proceeding%20of%20Energy%202012%20FINAL%20part%202.pdf

Adeniyi, A.G., Ighalo, J.O., **Odetoye, T.E. (2019a)**. Response surface modelling and optimisation of biodiesel production from avocado plant (*Persea americana*) oil, ***Indian Chemical Engineer***. 1-8, Published by Taylor and Francis. Available online at https://www.tandfonline.com/ doi/full/10.1080/00194506.2019.1658546.

Adeniyi, G.A., **Odetoye, T.E.,** Titiloye J.O., Ighalo, J.O. **(2019b)**. A thermodynamic study of rice husk (Oryza Sativa) Pyrolysis. ***European Journal of Sustainable Development Research***. 3(4) em0094. Available online at https://doi.org/10.29333/ejosdr/5830

Ajala E.O, Ajala M.A., Agbeleoba, E.D., **Odetoye T**.E., Eromonsele O.P, Ayanshola A.M. (2022) *Archachatina marginata* snail shell as a feedstock for the synthesis of solid catalysts for methanolysis of oil from palm kernel in an optimization process. Uniosun Journal of Engineering and Environmental Sciences, 4(1) 9-30.

Ajala E.O., Ajala M.A., **Odetoye T.E.,** Aderibigbe F.A., Osanyinpeju H.O. and Ayanshola M.A. **(2020)**. Thermal modification of chicken eggshell as heterogeneous catalyst for palm kernel oil biodiesel production in an optimization process, ***Biomass Conversion and Biorefinery***. 1-17. Published by Springer Nature Switzerland AG, Available online at https://link.springer.com/article/10.1007/s13399-020-00636-x

Ajala, E.O., Aberuagba, F., **Odetoye, T.E.** & Ajala, A.M. **(2015)**. Biodiesel sustainable energy replacement for petroleum-based diesel fuel-A review. ***ChemBioEng Reviews***.2 (3); 145-156. Published by Gesellschaft Deutscher Chemiker (German Chemical Society, GDCh) supported by DECHEMA (German Society for Chemical Technology and Biotechnology), VDI-GVC (VDI Society for Chemical and Process Engineering) and Wiley-VCH, Weinheim. Available online at https://onlinelibrary.wiley.com/doi/full/10.1002/cben.201400024

Ajala, E.O., Ajala, M.A., **Odetoye, T.E.**& Okunlola, A. T. **(2019)**. Synthesis of Solid Catalyst from Dolomite for Biodiesel Production using Palm Kernel Oil in an Optimization Process by Definitive Screening Design. ***Brazilian Journal of Chemical Engineering.*** 36(2); 979-994. Published by Brazillian Society of Chemical Engineering. Available online at http://dx.doi.org/10.1590/0104-6632.20190362s 20180516

Aladetuyi, A., Olatunji, G.A., Ogunniyi, D.S., **Odetoye, T.E.** & Oguntoye, S.O. **(2014)**. Production and characterization of biodiesel using palm kernel oil, fresh and recovered from spent bleaching earth. ***Biofuel Research Journal.*** 1 (4); 134- 138. Published by Green Wave Publishing of Canada. Available online at http://www.biofuel journal.com/article_7354_542.html

Amos O., **Odetoye T. E.**& D. S. Ogunniyi **(2021)**. Preparation and characterization of Zinc metal soap from shea butter (*Vitellaria paradoxa*), ***Journal of Nigerian Society of Physical Sciences,*** 3: 340–343.Published by the Nigerian Society of Physical Sciences. Available at https://journal.nsps.org.ng/index.php/jnsps/article/view/238/102.

Ajala, E.O., Aberuagba, F., **Odetoye, T.E.** & Ajala, A.M. **(2015)**. Biodiesel sustainable energy replacement for petroleum-based diesel fuel-A review. ***ChemBioEng Reviews.*** 2 (3);145-156. Published by Gesellschaft Deutscher Chemiker (German Chemical Society, GDCh) supported by DECHEMA (German Society for Chemical Technology and Biotechnology), VDI-GVC (VDI Society

for Chemical and Process Engineering) and Wiley-VCH, Weinheim. Available online at https://onlinelibrary.wiley.com/doi/full/10.1002/cben.201400024.

Ajala, E.O., Ajala, M.A., **Odetoye, T.E.** & Okunlola, A. T. **(2019):**Synthesis of Solid Catalyst from Dolomite for Biodiesel Production using Palm Kernel Oil in an Optimization Process by Definitive Screening Design. ***Brazilian Journal of Chemical Engineering.*** 36(2); 979-994. Published by Brazillian Society of Chemical Engineering. Available online at http://dx.doi.org/10.1590/0104-6632.20190362s20180516

Aladetuyi, A., Olatunji, G.A., Ogunniyi, D.S., **Odetoye, T.E.** & Oguntoye, S.O. **(2014)**. Production and characterization of biodiesel using palm kernel oil, fresh and recovered from spent bleaching earth.***Biofuel Research Journal.*** 1 (4); 134- 138. Published by Green Wave Publishing of Canada. Available online at http://www.biofueljournal.com/article_7354_542.html

Amos O., **Odetoye T. E.** *&* D. S. Ogunniyi **(2021)**. Preparation and characterization of Zinc metal soap from shea butter (*Vitellaria paradoxa*), ***Journal of Nigerian Society of Physical Sciences,*** 3: 340–343.Published by the Nigerian Society of Physical Sciences. Available at https://journal.nsps.org.ng/index.php/jnsps/article/view/238/102.

Amos O., **Odetoye T. E.** *&* D. S. Ogunniyi **(2022)**. Synthesis of metal carboxylates from almond seed oil (*Terminalia catappa*), ***FUDMA Journal of Sciences,*** 5(4): 382–388.Published by the Federal University of Dutsin-Ma, Katsina State. Available at https://www.fjs.fudutsinma.edu.ng/index.php/fjs/article/view/769/638.

Amos O. Ogunniyi, D.S. & **Odetoye T.E. (2016)**. Production of biodiesel from *Parinari polyandra* B. seed oil using bio-based catalysts. ***Nigerian Journal of Technological Development.*** 13 (1); 26-30, Published by Faculty of Engineering & Technology, University of Ilori, Ilorin. Available online athttps://www.ajol.info /index.php/njtd/article/download/144476/134122.

Awolola, G.V., Francis, P.U. & **Odetoye, T.E.** (2023). Synthesis of alkyd resins from black sesame (*Sesamum radiatum*) seed oil, FUOYE Journal of Engineering and Technology, 8(2) 223-227.

Bakare O.H. (2023) M. Eng. Project submitted to the Department of Chemical Engineering, University of Ilorin, Nigeria, unpublished.

Brundtland G.H. (1987) Our Common Future: United Nations Report of the World Commission on the Environment and Development.

Bulus & **Odetoye T.E. (2022)**. Biolubricant production from *Parinari polyandra* and *Azadirachta indica* seed oils using trimethylopropane polyol. ***Arid Zone Journal of Engineering, Technology and Environment***. 18 (2); 295-306. Published by the Faculty of Engineering, University of Maiduguri, Maiduguri Nigeria. Available online at https://www.azojete.com.ng/index.php/azojete/article/view/597/351.

Chakravarty K.H., Sadi M., Chakravarty H., Andersen J., Choudhury B. & Howard T.J., Arabkoohsar (2024). Pyrolysis Kinetics and potential utilization analysis of cereal biomass by-products; an experimental analysis for cleaner energy productions in India, Chemosphere 141420, In press.

Bridgwater, A.V. (2012). Review of fast pyrolysis of biomass and product upgrading. Biomass Bioenerg 38: 68–94.

Conti R., Jäger N., Neumann J., Apfelbacher A., Daschner R., Hornung A. (2017) Thermocatalytic reforming of biomass waste streams, Energy Technol 5: 104–110

Doss, P., Bridgwater, A.V. (2010) Synthesis of hydrocarbon via Fischer-Tropsch process, Proceeding of the Bioten conference on biomass, Biomass energy. CPL Press, Newbury, UK, 689 -693.

Enitan O.S. (2023). M.Eng. Project submitted to the Department of Chemical Engineering, University of Ilorin, Nigeria, unpublished.

Energy Information Administration (2023): Biomass Renewable Energy from Plants and animals, US Energy Information

Administration, Available online at https://www.eia.gov/energyexplained/biomass.

Gollakota, A.R. & Kishore N., Gu S. (2018). A review on hydrothermal liquefaction of biomass. Renew Sust Energ Rev, 81, Part 1: 1378-1392.

Goyal, H.B., Seal D. & Saxena, R.C. (2008). Bio-fuels from thermochemical conversion of renewable resources: A review. Renew Sust Energ Revs 12(2):504-517.

Guedes, R.E., Luna A.S. & Torres A.R. (2018) Operating parameters for bio-oil production in biomass pyrolysis: A review. Journal of Analytical Applied Pyrolysis 129:134–149.

Motojesi, O., Ogunniyi, D.S. & **Odetoye, T.E (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**.** Published by the Nigerian Society of Chemical Engineers. Available online at https://journal.nsche.org. ng/index.php/NSChE/issue/archive.

NNPC (2010). Automotive Biomass Ethanol Programme, Renewable Energy Division Biofuels Development in Nigeria, Presentation for National Conference on Clean Air, Clean Fuels and Vehicles, http://www.unep.org/transport/pcfv/pdf/nacconference.pdf, assessed online on 14/04/15.

Odekina G.C. (2023). Reps move to establish biofuels energy industry framework, Vanguard Newspaper, October, 3, 2023.

Odetoye O. A. *&* **Odetoye T. E. (2021)**. Disruptive Engineering: Maximising the Feedback Relationship between Industry 4.0 and the Nigerian Engineering Education Sector. ***FUOYE Journal of Engineering and Technology***, 6(4) 420-426. Published by Faculty of Engineering and Technology, Federal University of Oye-Ekiti, Nigeria. Available at http://journal. engineering.fuoye.edu.ng/index.php/engineer/article/view/672

Odetoye, T.E. & Ogunniyi, D.S. **(2024)**. Potential Nigerian seed oils for alkyds production: a review. NSE Technical Transactions, in press.

Odetoye T.E. & Ocheni M.L. **(2022)**. Thermochemical characterization of African oil bean for potential biofuel production, ***Chemistry Africa.*** 5(4); 1097-1101. Published by Springer Nature for Tunisian Chemical Society, Tunisia. Available online at http://linkspringer.com/ article/101007/s42250-022-00372-x

Odetoye T.E. Udoh A.J. & Ogunniyi D.S. **(2022)**. Parinari oil is a potential bio-based feedstock. A Review. ***FUW Trends in Science and Technology Journal*** 7 (1); 233-238. Published by the Federal, University of Wukari, Wukari, Nigeria. Available online at https://ftstjournal.com/ uploads/docs/71%20Article%2023pdf.

Odetoye T.E., Agu J. & Ajala E.O. **(2021)**. Biodiesel production from poultry wastes: Waste chicken fat and eggshell. Journal of Environmental Chemical Engineering. 9(4); 105654. Published by Elsevier. Available online at https://www.sciencedirect.com/science/article/abs/pii/S221334372100631X

Odetoye T.E. & Arowojobe F.D. **(2021)**. Circular economy: Biocomposite production from discarded low-density polyethene sachets and palm kernel shell fibres, ***Current Trends in Polymer Science***. 21;51-59. Published by Research Trends, India. Available online at http://www.researchtrends.net/tia/abstract.asp?in=0&vn=21&tid=2&aid=6904 &pub=2021&type=3.

Odetoye T.E., Ibarhiam S.F. & Titiloye J.O. **(2020a)**. Thermochemical Characterization of Biomass Residues and Wastes for Bioenergy In: ***Valorization of Biomass to Value-Added Commodities: Current Trends, Challenges, and Future Prospects***, Daramola M.O., Ayeni A. (Eds), 93-100, Published by Springer Nature, Switzerland. Available online at https://link.springer. com/chapter/10. 1007%2F978-3-030-38032-8_5.

Odetoye T.E.V Titiloye J.O. **(2020)**. Biomass Conversion by Pyrolysis Technology In: ***Valorization of Biomass to***

Value-Added Commodities: Current Trends, Challenges, and Future Prospects, Daramola M.O., Ayeni A. (Eds), 303-316, Published by Springer Nature, Switzerland. Available online at https://link.springer.com/chapter/10.1007/978-3-030-38032-8_15.

Odetoye T.E., Adeniyi A.G. & Akande O. **(2020b)**. Valorization of post-consumer polythene water sachet and *Parinari polyandra* shell residue for composites production. SN Applied Sciences.2;1828. Published by Springer Nature Switzerland AG. Available online at https://doi.org/10.1007/s42452-020-03641-x

Odetoye T.E. *&* Ashaolu O.O. **(2020)**. Preparation and water absorption properties of *Parinari polyandra* fruit shell reinforced epoxy composites. ***FUOYE Journal of Engineering and Technology***, 5(2) 87-91. Published by Faculty of Engineering and Technology, Federal University of Oye-Ekiti, Nigeria. Available at http://journal.engineering.fuoye.edu.ng/index.php/engineer/article/view/532.

Odetoye T.E., Ajala E.O. &T itiloye, J.O. **(2019a)**. A Review of bioenergy policy implementation in Ghana, Malawi and Nigeria. ***FUOYE Journal of Engineering and Technology***, 4(1); 87-91. Published by Faculty of Engineering and Technology, Federal University of Oye-Ekiti, Nigeria. Available at http://journal.engineering.fuoye.edu.ng/index.php/engineer/article/view/313.

Odetoye T.E., Ajala E.O. & Ogunniyi D.S. **(2019b)**. A Review of Biofuels Research in Nigeria. ***Arid Zone Journal of Engineering, Technology and Environment***. 15 (1); 153-162. Published by the Faculty of Engineering, University of Maiduguri, Maiduguri, Nigeria. Available online at https://www.azojete.com.ng/ index.php/azojete/article/view/254.

Odetoye T.E. & Amusan G.S. **(2019)**. Cocoa pod ash as bio-based catalyst for biodiesel production from waste chicken fat, ***Agricultural Engineering International: CIGR Journal.*** 21(4);144-151. Published by Agricultural Engineering

International: CIGR. Available online at https://cigrjournal .org/index.php/Ejounral/article/view/ 5492/3195.

Odetoye, T.E, Abu Barkar M.S. & Titiloye ,J.O. **(2018a)**. Pyrolysis of *Jatropha* shell and seed coat. ***Nigerian Journal of Technological Development***.16(2); 71.

Odetoye, T.E, AbuBarkar M.S. & Titiloye, J.O.**(2018b)**. Thermochemical characterisation of Nigerian Jatropha *curcas* fruit and seed residues for biofuel production. ***Energy, Ecology and Environment*** .3 (6); 330–337. Published by Joint Centeron Global Change and Earth System Science of the University of Maryland and Beijing Normal University, copyright: Springer Nature Switzerland AG. Available online at https://www.springerprofessional.de/en/thermochemical-characterization-of-nigerian-jatropha-curcasfrui/16171478

Odetoye T.E. Afolabi,T.J. & Onifade, K.R. **(2016)**. Effects of the extraction parameters on the quality characteristics of *Parinari polyandra* B. seed oil. ***Nigerian Journal of Technological Development*** 13 (2); 26-30, Published by Faculty of Engineering & Technology, University of Ilorin. A vailable online at https://www.ajol.info/index. php/njtd/article/view/152822.

Odetoye T.E. **(2015a)**. Fixing the Engineering Gender Divide In Nigeria: Picture It, APWEN Newsletter, Published by Association of Professional Women Engineers, Ilorin, Nigeria.

Odetoye, T.E. (2015b). A Review of Bioenergy Policy Implementation in Sub–Saharan Africa: Opportunities and Challenges - A case of Nigeria, Ghana, Malawi, South Africa and Zimbabwe. Paper presented at the European Conference on Sustainable Energy and Environment, July 9-12, 2015, Brighton, U.K.

Odetoye, T.E., Onifade, K.R., AbuBakar, M.S. & Titiloye, J.O. **(2014a)**. Pyrolysis of *Parinari polyandra* Benth fruit shell for bio-oil production. ***Biofuel Research Journal.*** 1 (3);85-90. Published by Green Wave Publishing of Canada. Available online at http://www.biofueljournal. com/article_6144_542.html.

Odetoye,**T.E.,** Ogunniyi, D.S. & Olatunji, G.A.**(2014b)**. Refining and characterization of *Parinari polyandra* Benth seed oil for industrialutilization. ***Nigerian Journal of Pure and Applied Sciences***. 2;2538 – 2551. Published by Faculties of Physical Sciences & of Life Sciences, University of Ilorin, Ilorin. Available online at njpas.com.ng/wp-content/uploads/2016/05/Odetoye-et-al.-2014.pdf.

Odetoye, T.E., Onifade, K.R., AbuBarkar, M.S. & Titiloye, J.O. **(2013a)**.Thermochemical characterisation of *Parinari polyandra* Benth fruit shell for bio-oil production. ***Industrial Crops and Product***. 44; 62-66 Published by Elsevier. Available at http://dx.doi.org/10.1016/j.indcrop.2012.10.013.

Odetoye, T.E, Ogunniyi, D.S. & Olatunji, G.A. **(2013b)**. Studies on the preparation of *Parinari polyandra* Benth seed oil alkyd resins, ***Journal of Applied Polymer Science***.127 (6); 4610-4616. Published by Wiley Publishers. Available online at http://onlinelibrary .wiley.com/doi/10.1002/app.37999/abstract.

Odetoye, T.E.,Ogunniyi, D.S. & Olatunji, G.A.**(2012)**. Improving *Jatropha curcas Linneaus* seed oil alkyd resins. ***Progress in OrganicCoatings***.73 (4);374 – 381.Published by Elsevier. Available online at http://www.sciencedirect.com/science/article/pii/S0300944011003559.

Odetoye, T.E. (2011). Recycling of poly urethane foams: a strategy in waste management and control**.** ***Nigerian Journal of Polymer Science and Technology.*** 8 (2); 140-151.

Odetoye, T.E., Ogunniyi, D.S. & Olatunji, G.A. (**2010)**. Preparation and evaluation of *Jatropha curcas Linneaus* seed oil alkyd resins. ***Industrial Crops and Product***.32 (3); 225 – 230. Published by Elsevier. Available online at http://www.sciencedirect.com/science/article/pii/S092666901000107X.

Odetoye, T.E., Ogunniyi, D.S. & Olatunji, G.A. **(2008)**. *Vegetable Oils as Industrial Raw Material*, **Proceedings of the First Kwara Chapter Conference of the Chemical Society of**

Nigeria (CSN), Ilorin, Nigeria,74-79, Published by CSN. Published by Polymer Institute of Nigeria.

Odetoye, T.E. (2017)., Just a Little Kindness In: Jide the Latecomer and Other Stories, Ikechi, C.N.(ed.), 11-14, Published by Jamiro Press Link, Nigeria.

Odetoye, T.E. (2019). Celebrate It: What God Says about the Sabbath, Ikechi, C.N.(ed.), 29-33, Published by SDAC., Nigeria.

Odetoye, T.E. (2019). The Clean Cup: Tell Me Another Story, Ikechi, C.N. (ed.), 18-20, Published by SDAC, Nigeria.

Odiase, P.O. & **Odetoye T.E. (2022)**. Production of biocomposites from *Parinari polyandra* fruit shell using waste low-density polyethylene as matrix. ***Arid Zone Journal of Engineering, Technology and Environment***. 18 (2); 209-216. Published by the Faculty of Engineering, University of Maiduguri, Maiduguri, Nigeria. Available online at https://www.azojete.com.ng/index.php/azojete/ article/view/598/343.

Ogundipe, S. & **Odetoye, T.E. (2023)**. Optimization of oil extraction from *Mucuna pruriens seeds* (velvet bean) for biodiesel production, a presentation at International Conference on Clean Energy in Africa 26 October, 2023, Afe Babalola University, Ado Ekiti, Nigeria. University of Ilorin, Ilorin, Nigeria.

Ogunniyi, D.S. & **Odetoye, T.E (2008)**. Preparation and evaluation of tobacco seed oil-modified alkyd resins. ***Bioresource Technology***. 99; 1300-1304. Published by Elsevier. Available online at http://www.com/sciencedirect.science/article/pii/S0960852407002325.

Ogunniyi, D.S. **(2013)**. My Adventure with Polymers, 125th University of Ilorin Inaugural Lecture, 1-2. Published by Library and Publications Committee, University of Ilorin, Ilorin, Nigeria.

Olalere, G. **(2022)**. M.Eng. Project submitted to the Department of Chemical Engineering, University of Ilorin, Nigeria, unpublished.

Otaru K. **(2023)**. M.Eng. Project submitted to the Department of Chemical Engineering, University of Ilorin, Nigeria, unpublished.

Pattiya, A., Titiloye, J.O. & Bridgwater, A.V., **(2008)**. Fast pyrolysis of cassava rhizome in the presence of catalysts. J Anal Appl Pyrolysis 81:72-79.

Suntivarakorn, R., Treedet W., Singbua, P. &Teeramaetawat, N. (2018) Fast pyrolysis from napier grass for pyrolysis oil production by using circulating fluidized bed reactor: improvement of pyrolysis system and production cost. **Energy Reports**4: 565-575.

Titiloye, J.O. & **Odetoye, T.E**. **(2013)**. Renew a bleenergy from biomass and biofuels: opportunities and challenges in Nigeria. ***Proceedings of 2nd International Conference and Workshop on Renewable Energy, Covenant University, Ota, Nigeria***. Alex Willoughby(ed). 104-115. Published by Covenant University, Ota Ogun State.

Titiloye, J.O., AbuBarkar, M.S. & **Odetoye, T.E (2013)**. Thermochemical characterization of agricultural wastes from West Africa. ***Industrial Crops and Product.*** 47;199–203.Published by Elsevier. Available online at http://dx.doi.org/ 10.1016/j.indcrop.2013.03.011.

Uddin, M.N., Techato, K., Taweekun, J., Rahman, M.M., Rasul, M.G.V Mahlia, T.M. Ashrafur, S.M.(2018) An Overview of Recent Developments in Biomass Pyrolysis Technologies. Energies11 (11) 3115.

Yusuf Y.O.**, Odetoye, T.E**. & Ogunniyi, D.S. (2024). Biocomposites development from agricultural residues towards circular economy In: *Material development in the contemporary time for sustainable development-**A Festschrift in honour of Prof. A.S Abdulkareem***, G.A Adeniyi. (ed.), 31-42. Published by the Department of Chemical Engineering, University of Ilorin, Nigeria.