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Special Issue
A Themed Issue in Honour of Professor Onukwuli Okechukwu Dominic (FAS).

This special issue is dedicated to Professor Onukwuli Okechukwu Dominic (FAS), marking his retirement and celebrating a remarkable career. His legacy of exemplary scholarship, mentorship, and commitment to advancing knowledge is commemorated in this collection of works.

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Impact of Allanblackia Floribunda Seed Shells and its Novel Utilization for Energy Growth

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Abstract

Industrialization is key to societal development and the utilization of abundant residues from organic waste helps to reduce overreliance on inorganic materials for energy and construction. In this research, a novel *Allanblackia Floribunda* seed shell was discovered as an alternative biocatalyst to existing biocatalyst. The ground fine powder of *Allanblackia Floribunda* Seed Shells was analyzed with a Thermogravimetric analyzer, Differential Scanning Calorimetry, X-ray Fluorescence, and Ultimate, and Proximate analysis to ascertain its thermal treatment suitability as biocatalyst for biodiesel making. The results indicate that the fine powder of *Allanblackia Floribunda* Seed Shells attained stable calcination at 740.24 ^{o}C at the third decomposition which is ideal for biodiesel production but can be calcined up to the fourth decomposition at 993.80 ^{o}C leaving a residue of 4.124% via the Thermogravimetric analyzer. The Differential Scanning Calorimetry showed that the maximum oxidation temperature of the biomaterial aligns with the third decomposition point of the Thermogravimetric analyzer. The calorific value derived from the mathematical model gave 23.65 MJ/kg indicating an acceptable energy potential source compared to other oil seed shells. Furthermore, X-ray fluorescence revealed the qualities of the compounds and elements present. The elements identified via X-ray fluorescence-FP were Mg, Al, Si, P, S, Cl, K, Ca, Ti, Mn, Fe, Cu, Nb, Sn, Zr, Ta, Zn, Ni, Co and O. Thus, the presence of these metals and few non-metals (S and P) can be utilized for biocatalyst production to boost the making of biodiesel, thereby contributing unique alternative biomaterial for energy sectors to strive globally.

Keywords: Biocatalyst, Biodiesel, Composite, Automobile and Aerospace

1. Introduction

Utilization of non-edible biomaterials in place of metallic materials and edible biomaterials has been a welcome concept provided it`s readily available. As the world searches for alternative biomaterials that can easily stand environmentally hazardous effects when utilized in several industrial applications (Iweka et al., 2024, Iweka et al., 2020), there is a need to investigate readily available but new non-edible biomaterial that can be employed as catalysts for biodiesel-making triggering the growth of energy shift (transitions), and contributions to scientific world. Biomaterials are typically leftovers from energy crops. Biomass, oil, and sugar crops are a subset of energy crops. They are feedstocks for producing biofuels, which can be substituted for fossil fuels (Tilvikienea et al., 2022; Suttibak et al., 2024). Oil crops are the main raw materials for bio-diesel production, while sugar crops are the main feedstocks for bioethanol. Biomass crops can be used in various biomass energy technologies, *e.g.*, biogas production and combustion (Suttibak et al., 2024; Iweka et al. 2021).

Suttibak et al. (2024) reported that oil seed crops like coconut, palm, soybean, Jatropha, sesame, yellow oleander, castor, tung etc., have high bio-oil values. Although, many biomaterials have been used such as plantain fiber, cotton fiber, coconut shell etc., to form reinforced composite for vehicle and airplane exterior bodies (Iloabachie et al., 2018; Sinebe et al., 2020; Hammiche et al., 2024). Additionally, cocoa pod and kola nut pod (Falowo and Betiku, 2022), banana peel (Okwelume et al., 2024), rubber seeds shell have also been reported as suitable catalysts for biodiesel production. However, the adoption of plantain stem, cocoa pod, kola nut pod, soybeans, coconut, and palm seed products as bio-oil, composite material, or catalyst will trigger food challenges. Thus, utilizing new non-edible biomaterials is a welcome initiative in this regard.

Allanbackia Floribunda Seed Shell is found globally, especially in African countries like Togo, Tanzania, Congo, Ghana, Angola, Nigeria, etc (Balogun et al., 2019; 2024). In Nigeria, it can be found in Uzere Delta State, Oyigbo Rivers State (Balogun et al., 2019; 2024), and Ovia community in Edo State (Irabor et al., 2021). *Allanblackia floribunda* referred *to* as Elephant`s rice belongs to the Clusiaceae Family (Irabor et al. 2021). *Allanblackia* tree contains a fruit figure 1, its seeds figure 2, and the seed shells figure 3. The bio-oil produced has been diversified into biodiesel, soap, and candlestick making (Adipah 2018; Balogun et al., 2019; Maduelosi et al., 2021) while the stem bark and leaves have been extracted for local medicine for humans and other animals treatment (Irabor et al., 2021). Additionally, *Irabor et al. (2021)* reported that *Allanblackia floribunda* seeds are used for ointment, soap, and margarine making. Brusotti et al. (2016) reported *Allanblackia floribunda* stem bark ethanol extract. Additionally, agricultural biowastes can be converted into energy through various processes like biochemical, mechanical, and thermochemical (Melikoglu et al., 2023). The biochemical approach converts agricultural biowastes to energy via the introduction of microorganisms or enzymes over a long duration. The mechanical approach produces green energy from agricultural biowastes with low output and high operation costs, but the utilization of the thermochemical approach produces high efficiency, reduces wastage, takes less time, and minimizes the emission of hazardous greenhouse gases (Melikoglu et al., 2023). The thermochemical approach comprises combustion, pyrolysis, and gasification (Melikoglu et al., 2023; Kazimierski et al., 2022). This biomass is eco-friendly (Neto et al., 2023; Okoro et al., 2019) and has demonstrated it can serve multipurpose utilization and boost any economy of a nation with its seed shells as another viable prospect that has been discarded always, and not yet converted to useful economic assets.

Thermal analysis is one of the approaches mostly used to investigate the thermal behavior and the temperature stability of any biomass (Luna et al. 2018; Torres et al., 2019; Neto et al., 2023). The thermal approach under study includes thermogravimetric analysis (TGA), Differential Scanning Calorimetry (DSC), X-ray fluorescence (XRF) spectrometry, and Proximate and Ultimate examination. The TGA measures the weight loss as a function of temperature. It provides details about the thermal qualities and decomposition mechanism of materials. The TGA can be deployed to derive a predictive model and values of ash, moisture, fixed carbon, etc. for calculating the grand calorific value (Siakia and Bardalai, 2018; Neto et al. 2023), but utilizing the ash, volatile matter, and fixed carbon compositions from proximate examination to compute the calorific value is more ideal as documented by Neto et al. (2023). The proximate examination is vital in ascertaining the quality and feasibility of a particular biomaterial to identify its best potential use, especially in green energy production (Racero-Galaraga et al., 2024). The results yield; ash, moisture, fixed carbon, and volatile matter values in percentage. By comprehending these variables, one can compare various types of biomaterials and identify the most effective ways to use or pretreat them to increase performance (Racero-Galaraga et al., 2024). Another branch related to this examination is the ultimate examination. This helps to ascertain the content of hydrogen, carbon, nitrogen, sulphur, and oxygen present in the examined biomaterial in contrast with established values from other types for effective utilization, especially in clean fuel and biocatalyst production. Differential Scanning Calorimetry (DSC) allows one to measure the thermal qualities of biomass by establishing a relationship between heat flows as a function of temperature (Neto et al., 2023). The DSC is used to analyze the thermal qualities of materials like polymers, biomass, and metallic materials. The DSC works by heating up to a specific temperature and cooling at a determined specific rate. All through this period, the DSC generates data and plots using the connected software (Sebastian 2023). The compound analysis of biomaterial helps to know its suitability for biofuel, and composite material utilization, and the instrument used is called XRF spectrometry (Morgan et al. 2015; Neto et al. 2023; Iweka et al. 2023).

However, to ascertain the seeds shell`s multipurpose usefulness, it is ideal to analyze the compounds and elemental components of the crushed Uzere Tallow Seed Shells (UTSS) via XRF, Proximate, and Ultimate examination. Additionally, determining its thermal qualities and stability via TGA and DSC and the composition of the variables from proximate examination via a documented equation by Neto et al. (2023) can be deployed in the computation of the calorific value (CV) needed in several energy utilization like biocatalyst production, biodiesel making, and as reinforced composite for the benefit of the society and research field. Yet none has looked into the *Allanblackia Floribunda* seed shells` suitability as catalysts for biodiesel making, as the shells are always discarded as invaluable biomaterial, left to decay or burnt in the open air. Thus, there is a need for the government to boost green energy generation via the agricultural sector by encouraging unemployed youths to go into farming and cultivation of energy trees with immense economic value like Tallow trees known as *Allanblackia Floribunda* trees, triggering a blue economy (Raza et al. 2023).

Figure 1: *Allanblackia Floribunda* fruit with seeds

Figure 2: *Allanblackia Floribunda* seeds

Figure 3: *Allanblackia Floribunda* seed shells

2.0 Materials and methods

2.1 Acquisition of materials

The virgin Tallow seed shells` was collected from a bush at Uzere via local Farmers, Isoko South Local Government Area, Nigeria. The chemical compounds and promoters deployed for the Lab examination adhered to scientific norms.

2.2 Tallow seed shells` preparation

The Tallow seed cultivated from the bush in Uzere was washed with tap water and sun-dried for three 4days to allow easy removal of the shell from the seeds. It was crushed into fine powder with an energy-powered grinder (KENWOOD) of 10000W, 4 Litre. Thereafter, it was sieved using a mesh size of 65mm. Then, a raw fine particle of UTSS was kept in an air-tight rubber bottle and sent to a lab for XRF, DC, TGA, Ultimate, and Proximate analysis as depicted in figure 4.

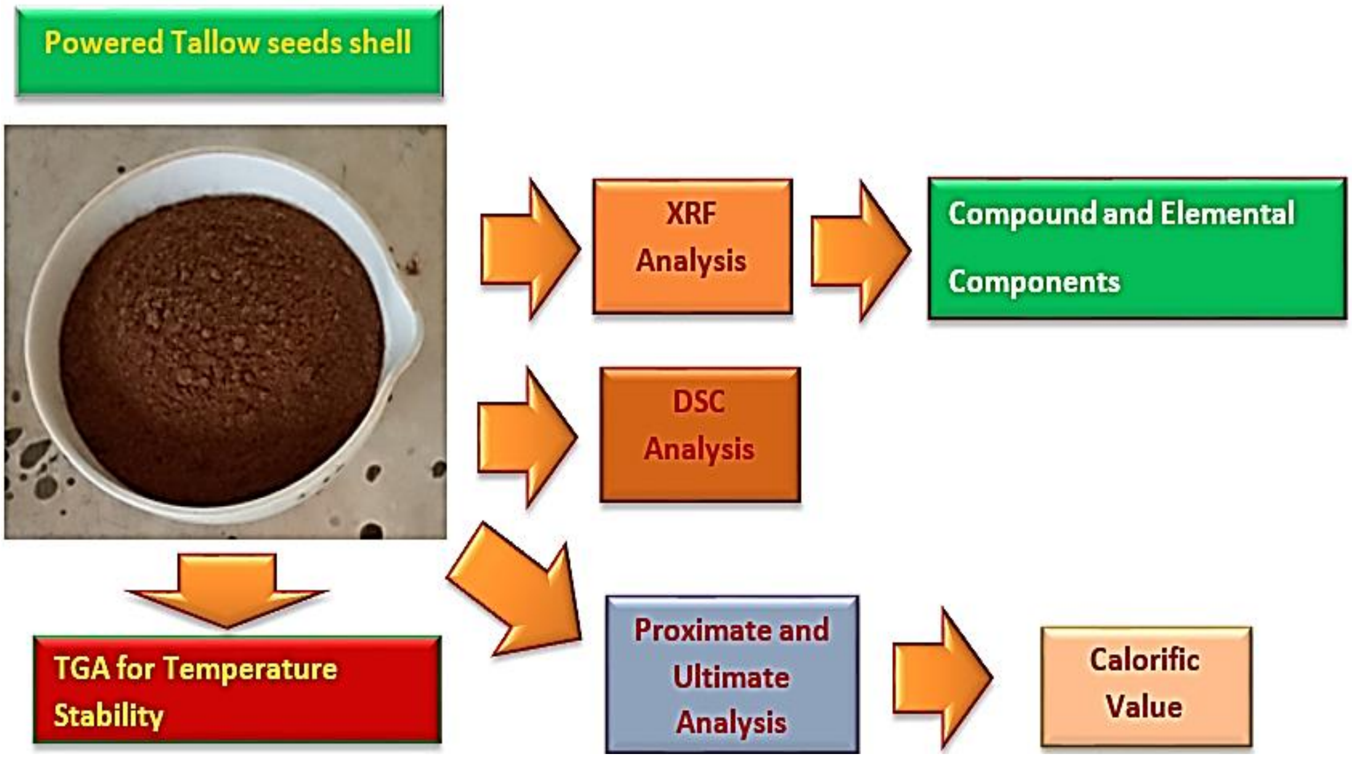

Figure 4: Schematic characterization approach

2.3 Thermal Analysis

2.3.1 XRF (XRS-FP) analysis

The fine powder UTSS was characterized to determine the acidic-basic elements via the XRS-FP Crossroad scientific device as depicted in figure 4.

2.3.2 TGA procedure

Thermo-gravimetric analyzer with model number 2950 connected with Universal Analysis 2000 software was used to determine a suitable thermal treatment temperature of the Tallow seed shells for catalysis. A portion of the sample was injected into a platinum plate and slotted into the TGA 2950 analyzer. A platinum plate was used as the holder because it heats up easily and as well dissipates heat very easily. The temperature of the analyzer was set at 1000 ^oC with a flow rate of 100 ml/min and helium was deployed to prevent an oxidation environment to generate a plot of weight (%) vs temperature (^oC) and generate an output of derivative weight loss (%/ ^oC) i.e. its velocity (rate of change).

2.3.3. DSC procedure

The Differential Scanning Calorimetry with model number 1600 DTA connected with universal analysis 2000 software was deployed to analyze the heat flow against temperature and generate an output of derivative heat flow (mW/ ^oC) i.e. its velocity (rate of change).

2.4 Proximate and Ultimate procedure

2.4.1 Proximate procedure

The proximate analysis comprises values from moisture content, volatile matter, ash, and fixed carbon.

***2.4.1.1** Percentage Moisture Content (PMC)*

Mass loss after two hours at 105°C under N_2 purge was used to calculate the samples' moisture content. A ceramic crucible was filled with around 0.5 g of the air-dried sample. To guarantee that all oxygen was eliminated, the samples were put inside a Lindberg muffle furnace that had first been purged with N_2 gas for at least 20 minutes at a flow rate of 3 L min^{-1}. The furnace was shut off after the two hours of heating, and the samples were moved right away to a desiccator where they cooled for an hour before being evaluated.

$$MC = \frac{Wc - Dc}{Wc} \times 100$$

where Wc is the Air dried weight of the sample
DC is the Oven-dried weight of the sample at 103 ℃
MC = Moisture content.

2.4.1.2. Volatile matter (VM)

Volatile matter was determined by heating the oven-dry samples under N_2 purge at 850◦C. The crucibles containing the samples were stored in a stainless steel container within a muffle furnace and enclosed with ceramic tops while they were heating. A N_2 purge line and thermocouple were inserted through the top of the furnace and down into the stainless steel box through a small hole in the box cover. The box was purged with N_2 gas for about 5 min at a flow rate of 5 L min^{-1}. Following the first purge, the furnace was regulated to the required peak separation temperature, the N_2 flow rate was lowered to 3 L min^{-1}, and it was then switched on. Throughout the heating procedures, the temperature within the stainless steel container was documented every 60 seconds. Once the temperature inside of the stainless steel box reached 850◦C separation temperature, the furnace was switched off and the furnace door opened. The N_2 purge inside the stainless-steel box was maintained (3 L min^{-1}) during cool down (2–4 h), after which the crucibles were weighed.

$$\text{Volatile matter} = \frac{B - C}{B} \times 100$$

Where; B is the Air-dried weight of the sample
C is the Furnace calcined weight of the sample at 900 ℃

2.4.1.3 Ash value (AV)

Using the same muffle furnace, the sample was heated to 730°C in an airy environment to assess its ash value (content). Crucible tops were taken off to guarantee full combustion, and the furnace was continuously cleansed with a low flow of house air (1.5 L min^{-1}). 730°C was reached in the furnace and maintained there for 8 hours. After ash was produced, the samples were moved to a desiccator for cooling after the furnace was turned off and left to cool for an hour. After the crucibles were weighed, the weight of the empty crucible was deducted to calculate the quantity of ash. Assessments were made in triplicate for all stated proximate analysis data.

$$AV = \frac{D}{B} \times 100$$

where D is the new weight of the sample
B is the Initial of sample at 103 ℃, AV = Ash value (%)

2.4.1.4 Fixed Carbon

The percentage fixed carbon, PFC was calculated by subtracting the sum of percentage volatile matter (PVM) and percentage ash content (PAC) from 100. A "distinction" is typically used to determine the carbon composition, meaning that all other constituents are subtracted from 100 as percentages, and the remaining amount is presumed to be the proportion of fixed carbon. This was determined using;

$$F = 100 – (VM + AV)$$

2.4.2 Ultimate analysis

This was analyzed to get carbon, hydrogen, nitrogen, and sulphur. The summation of these values subtracted from 100 gives the oxygen value present.

2.5 Calorific Value (CV) procedure

The proximate parameter values and a recommended equation reported in the discussion section were activated in the computation of the CV to know the specific energy of the UTSS. Thus, this energy can be utilized for combustion, heating, and electricity both for industrial and household activities.

3.0 Outcomes and Discussion

3.1. Qualities of the Uzere Allanblackia Floribunda Seed Shells via XRS-FP

The compound and elemental components of the powered Uzere *Allanblackia Floribunda* Seed Shells are depicted in table 1. The XRS-FP analyzer detected the chemicals and elements found in powdered Allanblackia Floribunda seed shells. The findings demonstrate the existence of significant elements that include crucial metals for energy shift (transition), such as silicon and tin (Kumar et al. 2020). It also comprises rare earth elements that are hard to discover but accumulate in many regions like tantalum, cobalt, zirconium, and niobium. Finally yet importantly, elements such as calcium, potassium, magnesium, sulphur, iron, aluminium, etc., are also essential for the growth of technology and energy shift. Consequently, their utilization as catalysts for biodiesel making, biomedical applications, capacitors, alloys, composites, biomaterials, airplane fuselage, automobile bodies, and other chemical sectors, etc. Demonstrating multipurpose utilization for these new seed shells, especially in biodiesel formulation.

Table 1: XRS-FP Analysis of the powered Uzere Tallow Seed Shells (UTSS)

Compounds		Elements	
Compositions	**Concentrations**	**Compositions**	**Concentrations**
SiO_2	6.66	O	33.50
Fe_2O_3	4.69	Mg	8.83
MnO	0.91	Al	6.49
CuO	0.7	Si	3.11
Nb_2O_5	1.75	P	1.21
P_2O_5	2.78	S	2.82
SO_3	7.04	Cl	3.16
CaO	16.70	K	14.32
MgO	14.63	Ca	11.93
K_2O	17.25	Ti	0.39
Al_2O_3	12.26	Mn	0.70
Ta_2O_5	1.41	Fe	3.28
TiO_2	0.66	Cu	0.56
Cl	3.16	Nb	1.23
ZrO_2	0.59	Sn	6.52
SnO_2	8.28	Zr	0.44
ZnO	0.07	Ta	1.15
NiO	0.02	Zn	0.06
CoO	0.71	Ni	0.02
		Co	0.02

3.2 TGA Analysis of the Tallow Seed Shells

This gives an output of derivative weight (%/ºC) which is the blue line. The green curve is the standard reaction curve while the blue curve is the derivative weight loss. The derivative curve is used to interpret the rate of change happening (decomposition) across each temperature level. From the plot, the first decomposition was observed at 110 ºC with 11.29% ash generated due to the moisture content present as corroborated by the deflected downward u-curve of the derivative weight loss curve. The second decomposition displays an increase in oxygenation temperature resulting in 5.46% ash being generated at 214.3 ºC as corroborated by the derivative weight loss curve. The combustion continued until a stable temperature needed to form a catalyst for biodiesel production was observed at the third decomposition, which is at 740.28 ºC with 25.62% carbon left. The fourth decomposition was observed at 993.80 ºC with ash (residue) of 4.124% is corroborated by its fragile weight and a high combustion rate as observed in a muffle furnace when it was subjected to heat at 700 ºC for 1hour as described in figure 5. Where the green colour represents the standard reaction of the weight loss as a function of temperature and the blue colour represent the derived weight loss which is the rate of change (velocity).

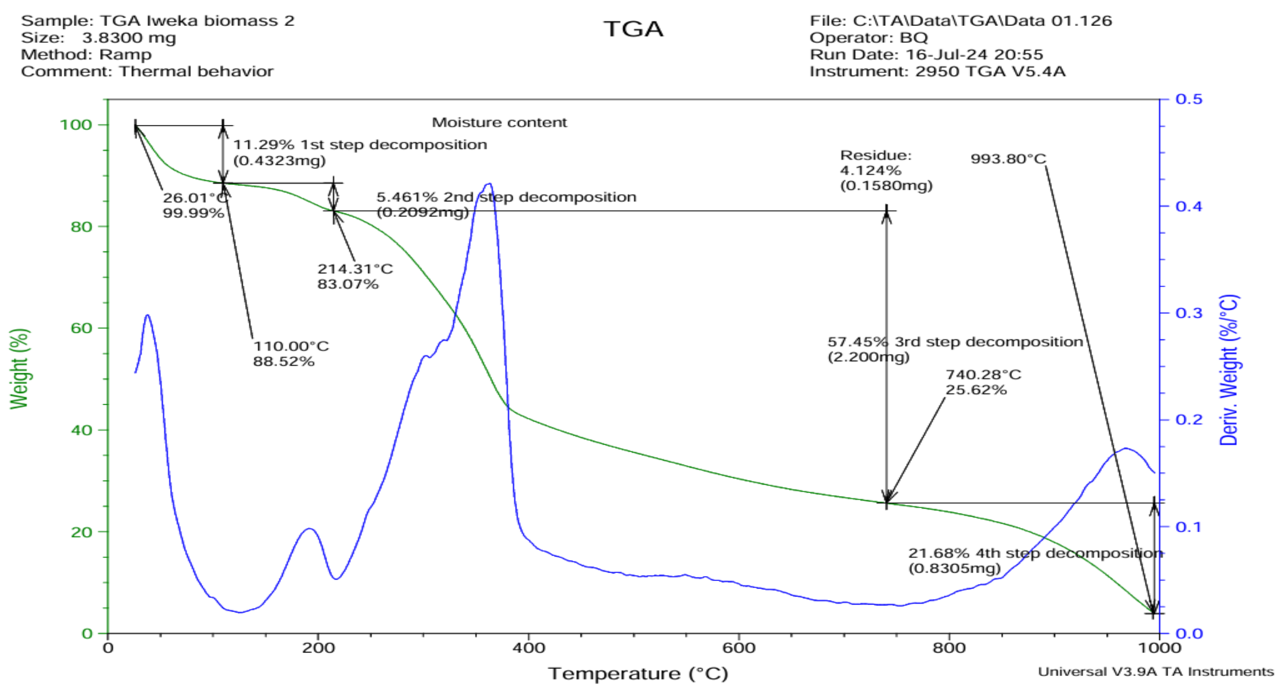

Figure 5: Raw powder UTSS TGA of weight vs temperature.

A downward spiral of the blue curve demonstrates an endothermic response where heat is absorbed from the surroundings to the system while an upward spiral of the blue curve demonstrates an exothermic response where heat is emitted to the surrounding from the system. Thus, the downward spiral of the blue curve at the first decomposition indicates the presence of moisture in the sample being analyzed and the DSC plot figure 6 corroborates this. The acceleration of the curve at 200 ºC shows an oxidation temperature depicting an exothermic response, a quick downward spiral (endothermic), and then, an exothermic reaction till it gets to the second decomposition at 5.461% residue and 88.52% at 214.31 ºC of the biomass remaining. The steady curve observed between 400 – 700 ºC shows a steady reaction. Thus, the TGA generated 11.29 % moisture value at 110 ºC and residues 4.12 % at 993.8 ºC. The high moisture might be based on the means of storage before utilization compared to the moisture composition derived from the mathematically computed value as described in Eq. (2).

3.3 DSC analysis of the raw powdered form

This was used to determine a suitable oxidation temperature point. From figure 6 it was observed using the blue curve as a guide to the normal reaction curve (green), that the biomass combusts when heated up initially. Thereafter, there was a downward spiral between 50 ºC – 100 ºC indicating that the biomass contained moisture due to poor storage of the biomaterial before usage. The downward curve was visible at 74.36 ºC. At this stage, the biomass absorbed heat indicating an endothermic response. It accelerated a little indicating an exothermic response

(Exo up) because heat was liberated to the surroundings from the system. It then maintained a steady reaction until an oxidation temperature was observed triggering an Exo up (exothermic reaction) at 304.22 °C. This noticeable oxidation temperature at this point aligns with the third decomposition (breakdown) of the TGA. Thus, this reaction aligns with the TGA plot in figure 5. Additionally, a sharp Exo up was observed at 350.76 °C.

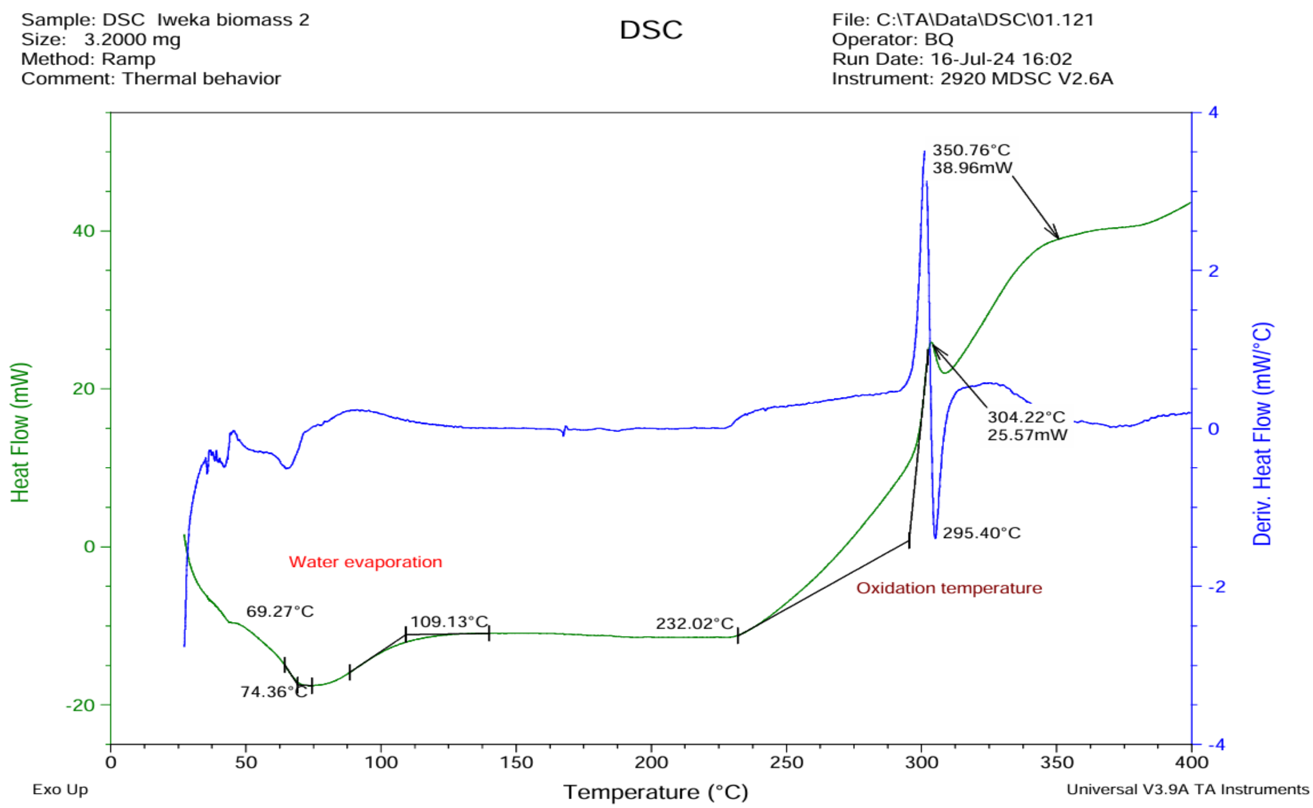

Figure 6: Raw powdered UTSS DSC plot of weight vs temperature

3.4 Proximate and Ultimate analysis

Table 2: UTSS powder proximate result

Biomass (%)	Moisture	Ash	Volatile matter	Fixed carbon	CV (MJ/kg)	Reference
This Study	3.36	4.4	51.21	44.39	23.64562	
Coconut coat	7.3	1.4	69.2	30.1	19.86	a
Groundnut shell	4.0	17.2	70.5	12.2	15.4	b
Neem Shell	12.7	3.8	81.8	14.4	20.40	a
Palm Kernel cot	11.0	2.3	74.59	21.87	21.5	b
Tung outer coat	0.25	10.2	66.8	22.96	17.6	b

Source: a = Neto et al., 2023, b = Suttibak et al., 2024

Table 3: UTSS powder ultimate result

Biomass (%)	Carbon	Hydrogen	Nitrogen	Sulphur	Oxygen	Reference
This Study	55.50	7.276	3.783	0.006	33.435	
Groundnut shell	36.6	5.7	3.1	0.2	37.1	b
Palm Kernel coat	55.9	5.98	0.09	0.2	35.5	b
Tung outer coat	43	5.96	0.56	0.06	40.2	b

3.5 Calorific Value Report

Here, the calorific value in MJ/kg is calculated using Eq. (1) as documented by Neto et al.(2023). Thus, the energy in the UTSS can exploited as an energy source for heating, cooking, electricity, etc for both industrial and household activities.

Additionally, it can also be used for biodiesel, catalysts, and composite materials for exterior parts of automobiles and airplanes plus electronic components.

$$CV\ \left(\frac{MJ}{kg}\right) = 0.3536 * F + 0.1559 * Vm - 0.0078 * A \tag{1}$$

Where F = fixed carbon, Vm = volatile matter, and A = ash value while 0.3536, 0.1559, and 0.0078 are the constants tagged constant 1, constant 2, and constant 3 respectively. The calorific value (CV) is the same as High Heating Value (HHV)

Inserting these values into Eqn. (1) gives CV (HHV) as 22.45753 MJ/kg in Eq. (2)

$$CV\ \left(\frac{MJ}{kg}\right) = 0.3536 * 44.39 + 0.1559 * 51.21 - 0.0078 * 4.4$$

$$CV\ \left(\frac{MJ}{kg}\right) = 23.64562\ \text{MJ/kg} \tag{2}$$

This shows that the high-energy potential of 23.64562 MJ/kg of UTSS can be harnessed into thermal energy for cooking, heating, and other industrial applications. Thereby, adding extra value to the already commercialized seed oil and leaves. The seed`s oil is used for making; soap, local cream, candlesticks, biodiesel, etc., while its leaves are for local medicine and the seed shells are always discarded as waste. Converting the discarded shells to another polished biocatalyst for biodiesel making is a novel approach that has not been identified by any researcher until now.

3.6 Validation of Report

This research was validated by comparing the Proximate, Ultimate, and HHV as described in table 2 and table 3 which indicated that UTSS powder has the highest calorific value of 23.65 MJ/kg compared to others reported by Neto et al., 2023 and Suttibak et al., 2024. Furthermore, the sulphur percentage present in the UTSS powder was negligible compared to that obtained from the groundnut coat, palm kernel shell, and tung outer coat as illustrated in table 3. Hence, it was observed that the energy potential of tallow seed shells is within the accepted limit. Additionally, the XRF elemental results (Mg, Al, Si, P, S, Cl, K, Ca, Ti, Mn, Fe, Cu, Nb, Sn, Zr, Ta, Zn, Ni, Co and O), show that the tallow seed shells is a good potential energy source. This aligns with the fuel qualities of neem seed shells (K, Ca, P, S, Ti, Fe, Sr, Zn, and Rb) generated via XRF as documented by Neto et al. (2023). Thus, the tallow seed shells can be activated as biocatalyst when thermally treated for biodiesel making. Also, it can be activated alone as solid fuels for cooking, heating, and as composite biomaterials when reinforced with certain chemical agents, thereby, adding more value to the products from the tallow tree for economic benefit of any nation that plants the tree.

4.0 Conclusion

Industrialization is key to societal development and the utilization of abundant residues from organic waste helps to reduce overreliance on inorganic materials for energy and construction. Biowaste is best utilized when the government and private organizations set up industries, especially in rural areas with abundant biowaste. In this research, a novel *Allanblackia Floribunda* seed shell was discovered as an alternative biocatalyst to existing biocatalyst. The ground fine powder of *Allanblackia Floribunda* Seed Shells was analyzed with a Thermogravimetric analyzer, Differential Scanning Calorimetry, X-ray Fluorescence, and Ultimate, and Proximate analysis to ascertain its thermal treatment suitability as biocatalyst for biodiesel making. The results indicate that the fine powder of Allanblackia Floribunda Seeds attained stable calcination at 740.24 ^oC at the third decomposition which is ideal for biodiesel production but can be calcined up to the fourth decomposition at 993.80 ^oC leaving a residue of 4.124% via the Thermogravimetric analyzer. The Differential Scanning Calorimetry showed that the point of water evaporation (heat absorb) and maximum oxidation temperature (heat liberated) of the biomaterial align with the first and third decomposition points respectively of the Thermogravimetric analyzer. The Ultimate analysis results indicate high combustibility because of a high proportion of carbon content and with great energy storage due to the oxygen %. Also, the calorific value derived from the mathematical model gave 23.65 MJ/kg indicating an acceptable energy potential source, a deviation from other oil seed shell content. Furthermore, X-ray fluorescence revealed the qualities of the compounds and elements present. The elements identified via X-ray fluorescence-FP were Mg, Al, Si, P, S, Cl, K, Ca, Ti, Mn, Fe, Cu, Nb, Sn, Zr, Ta, Zn, Ni, Co, and O. Thus, the presence of these metals especially, Si, Ca, Al, Mg, and few non-metals (S and P) can be utilized for biocatalyst production to boost the making of biodiesel. Additionally, these unique new shells can be employed in making the exterior parts of aerospace, car bodies, capacitors, biomedical devices, etc., thereby contributing unique alternative biomaterials for energy and manufacturing sectors to strive globally with a view of reducing unemployment and rural-urban movement of able youths.

5.0 Recommendation for future research

Prospectus scholars can look into the best inorganic chemicals to reinforce the tallow seed shell for composite biomaterials with the need to boost the production of aerospace, electronics, and car parts. Additionally, the case of the thermally treated shell being documented as a biocatalyst for biodiesel production has been worked on by Iweka et al. and the manuscript is already under review by a particular journal.

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Nomenclature

CV = Calorific value, MJ/kg
HHV = High heating value, MJ/kg;
F= Fixed carbon, %;
AV= Acid value, %;
Vm= Volatile matter, %;
MC= Moisture content, %;

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