Cogent Engineering

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oaen20

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To cite this article: Esther Nneka Anosike-Francis, Gina Odochi Ihekweme, Paschal Ateb Ubi, Ifeyinwa Ijeoma Obianyo, Seun Jesuloluwa, Adekunle Akanni Adeleke, Prabhu Paramasivam, Azikiwe Peter Onwualu & Rasoamalala Vololonirina (2025) Characterization and assessment of selected agricultural residues of Nigerian origin for building applications, Cogent Engineering, 12:1, 2435594, DOI: 10.1080/23311916.2024.2435594

To link to this article: https://doi.org/10.1080/23311916.2024.2435594

Published online: 22 Dec 2024.

COGENT ENGINEERING
2025, VOL. 12, NO. 1, 2435594
https://doi.org/10.1080/23311916.2024.2435594

MATERIAL ENGINEERING | RESEARCH ARTICLE

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Characterization and assessment of selected agricultural residues of Nigerian origin for building applications

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ABSTRACT

The high rate of agricultural residue generation in Nigeria in recent times poses a serious environmental hazard. Thus, there is a need to valorize these residues for various engineering applications. Five Nigerian agricultural residues (okro, plantain, jute, kenaf, and sisal) were studied to determine their potential for forming natural fiber composites for building applications. The samples were subjected to a process of peeling and immersion in water for 15–20 days to facilitate the degradation of microbial cells and ease the extraction of fibers. Proximate and lignocellulose analyses of the samples were conducted according to the American Standard for Testing and Materials (ASTM) specifications. The physico-mechanical and thermal properties of the agricultural residues were examined using an Intron universal testing machine and a thermogravimetric analyzer. The fiber phase analysis revealed a crystallinity index range of 41.20–66.08% and a crystallite size of 30.79–84.00 nm, indicating that the fibers were thermally stable above 280 °C. Fourier Transform Infrared analysis provided conclusive evidence of the presence of distinct chemical compositions and their associated functional groups. The study contributes a reliable database for agricultural residues in Nigeria, particularly for construction applications. It is also being utilized to inform the design and implementation of manufacturing processes for roofing tiles and boards intended for general applications

ARTICLE HISTORY
Received 2 October 2024
Revised 22 November 2024
Accepted 25 November 2024

KEYWORDS
Natural fibres; okro; plantain; jute; kenaf; sisal

SUBJECTS
Mechanical engineering; power & energy; technology; clean tech

1. Introduction

The need to curb environmental degradation due to increasing agricultural residues, heightened awareness of the urgent necessity for responsible resource utilization, allowing for growth without escalating resource utilization, and employing a more environmentally friendly alternative to synthetic fiber has increased the research on the use of various types of biomass. According to the Food and Agriculture Organization, in 2002, the agricultural sector in developing countries will grow by 13%, or 120 million hectares, between 1999 and 2030 (Food and Agriculture Organization of the United Nations, 2002). These residues are commonly disposed of by burning or dumping in landfills, thus negatively affecting climate. They are the dominant source of local air pollution and emit approximately 18% of the global carbon dioxide (CO_2) and other greenhouse gases (Chen et al., 2017; Devi et al., 2017). This act is on the rise in developing countries, including Nigeria, owing to the difficulty in collecting, recycling, and disposing of increasing residues in a sustainable manner. To save the environment, there should be a correlation between the biomass produced and its utilization (Sharma et al.,

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2022). Between 2000 and 2006, Nigeria had an estimated annual total of 55.9 Tg of some selected agricultural residue (Iye & Bilsborrow, 2013). One of the ways to facilitate the easy use of natural fibers of Nigerian origin is to understand their chemical, physical, mechanical, and thermal properties in a database. Natural fibers and their composites have been studied for use in the automotive industry (Ubi et al., 2024), construction (Anosike-Francis et al., 2022; Nair & Dasari, 2022), biofuels (Tudu et al., 2024; Uzoagba et al., 2024), and the development of diverse food products and sustainable packaging (Soleimanian et al., 2022; Sydow & Bieńczak, 2019). The characteristics of natural fibers can be affected by a wide range of factors, including plant age, species, conditions for growth, harvesting methods, humidity levels, soil quality, temperature, and processing practices (Singh, 2019).

In a previous study, Manimaran et al. (2019) extracted and characterized cellulosic fibers derived from the peduncle of red bananas. The researchers noted that the fiber possessed features that make it a viable option as a natural reinforcement substance for the production of biocomposites with possible applications in several fields. he development of a green nano-biocomposite using jute and soy seeds, along with glutaraldehyde as a curing agent, by (Behera & Mohanty, 2021) resulted in a composite with mechanical properties comparable to existing jute composites on the market and thermal stability up to 292 °C. This composite can be used in furniture and automobile interiors. Diyana et al. (2021) investigated the utilization of *Pandanus amaryllifolius* fibers as a potential reinforcement in polymer composites. The fibers were extracted using a water-retting-extraction technique. The results of the investigation indicate that *Pandanus amaryllifolius* fibers could be used as a substitute reinforcement, particularly in the context of bio-based polymer matrices. In a previous study, Dalmis et al. (2020) investigated the potential use of *Chrysanthemum morifolium* stem fibers as an underutilized resource for reinforcing composite materials. The findings of this study suggest the use of these fibers as an unique and environmentally sustainable reinforcement option for green polymer composites. The fibers demonstrate a low density, an acceptable level of tensile strength, a high degree of surface hydrophobicity, and an outstanding degree of surface roughness.

Although there is growing research on natural fibers and their composites, many Nigerian residues have not been individually assessed or evaluated for their potential applications, which is the gap in knowledge for this research. Previous research has predominantly focused on investigating the physical characteristics of various types of fibers, such as fiber length, lumen width, and diameter (Kumar et al., 2023), as well as selected properties based on the perceived area of application or as part of a composite (Adeniyi et al., 2020; Ali et al., 2022). Various characterizations of these fibers, particularly those that have not been previously documented, will yield valuable insights into their properties, whereas the existing characterizations will be subjected to validation or refutation through the present investigation. The current investigation encompasses the evaluation of okra, plantain peduncle, sisal, and jute fibers.

Okra, known in English as lady's fingers, with the botanical name *Abelmoschus esculentus*, is a hairy annual plant of the Malvaceae family. This vegetable species is highly tolerant to heat and drought, making it one of the most resilient in the world. Additionally, it can thrive in soils with high clay content and varying levels of moisture. In 2018, seven African countries ranked among the top ten global producers of okra, with Nigeria in second place (2 million tons of production) after India (Food & Agriculture Organization of the United Nations, 2020).

Plantain (*Musa paradisiaca*), or cooking banana, is a plant of the banana family (*Musaceae*) that is produced mostly in the southern part of Nigeria. Plantain fruit is a staple food in Nigeria and is the third most important plant grown after cassava and yam (Jekayinfa et al., 2012). Nigeria is positioned sixth globally and holds the distinction of being the largest producer in the West African region. The country's annual production of approximately 2.4 million metric tons originates primarily from the southern states (Ekpete et al., 2017), and as such, significant amounts of trash are frequently produced from peels.

Agave sisalana, commonly referred to as sisal, is a member of the Asparagaceae family and indigenous to southern Mexico. It has been extensively cultivated and established in various countries. The utilization of sisal, a robust and coarse fiber, is experiencing a rise in prominence within the realm of composite materials, specifically in the domains of automobiles, furniture, and construction. In addition, sisal is increasingly being incorporated into the manufacturing processes of plastics and paper products. The anticipated global production of sisal and henequen, both types of agave fiber, is approximately 300,000 metric tons, with a combined market worth

of $75 million (Simpson, 2019; Tropical Plants Database, Ken Fern, n.d.).

Jute is an organic fiber with a lustrous, golden appearance that is obtained from the bark of the white jute plant (*Corchorus capsularis*). Jute is a crop with a yearly growth cycle that typically spans approximately 120 days, occurring from April or May to July or August. The species exhibits robust growth in regions characterized by tropical lowland environments, where relative humidity levels range from 60 to 90%. Jute is a crop that relies on rainfall for its water supply and has minimal reliance on fertilizers or insecticides. The average yield of dried jute fiber per acre was approximately 2 t. Jute is considered a highly cost-effective natural fiber, ranking next only to cotton as it relates to both production volume and versatility in applications. The jute fibre possesses the characteristic of being entirely biodegradable and recyclable, rendering it environmentally friendly. One hectare of jute plants has been observed to sequester approximately 15 tons of CO_2 while simultaneously releasing approximately 11 tons of oxygen (Food and Agriculture Organisation of the United Nations, n.d). Several studies have shown that natural fibers can be used in composite formation to improve the mechanical, physical, and thermal properties. This study characterized and analyzed four prevalent Nigerian agricultural residues, namely okra, jute, sisal, and green plantain peduncle, using Fourier transform infrared spectroscopy, chemical analysis, thermogravimetric analysis (TGA), Archimedes density method, X-ray diffraction (XRD), single-fiber testing, and scanning electron microscopy (SEM). Their properties were optimized for value addition and potential applications in sustainable buildings.

2. Materials and methods

2.1. Materials

The residues considered for assessment in this study were the okra, jute, sisal, and plantain peduncles. Okra stems were collected after harvest from a farm in Shebwokpma, Karu, and Nassarawa. Plantain peduncles were obtained from Zuba Market, Abuja, whereas sisal and jute were obtained from Zaria, Kaduna State, Nigeria.

2.2. Extraction of fibres

The extraction process for the fibers followed the scheme shown in Figure 1. The initial physical processing, such as cleaning and separation of pebbles, was performed on the materials. The samples were peeled and immersed in water for 15–20 days, allowing for sufficient microbial decomposition and ease of fiber extraction. The fibers that were obtained were subjected to multiple washes using tap water, rinsed with distilled water, and subsequently left to dry in ambient air. They were then cut into 50 cm lengths and stored in a moisture-proof container following the procedure of Ali et al. (Ali et al., 2022). Samples of the extracted fibers are shown in Figure 2.

2.2. Characterization of the extracted combed fibres

2.2.1. Proximate and lignocellulosic content analyses

Prior to chemical analysis, the fiber samples underwent a process of oven-dried at a temperature of 105 °C for 2 hours. Following the removal of surplus moisture from the fibers, the cellulose and hemicellulose contents of the fibers were assessed according to the procedure established in a prior investigation conducted by Anosike-Francis et al. (2022) and Natrayan et al. (2024). The moisture content of the fibers was determined using the mass-loss method. The importance of this approach is that it accurately assesses the amount of water present in a sample. By measuring the weight before and after drying, one can quantify the moisture content, which is essential for various applications, including processing, quality control, and storage of materials. A pre-weighed crucible was used to hold 10 g of each type of fiber. The crucible was then placed in a Memmert oven at 105 °C until a constant weight was obtained. Equation (1) was used to compute the moisture content values.

$$\%M.C = \frac{M_a - (M_2 - M_1)}{M_a} \times 100 \quad (1)$$

where $M.C$ represents the moisture content of the sample, M_a is the initial sample weight before oven drying, M_1 represents the weight of the unfilled crucible, and M_2 represents the weight of the crucible with the sample after drying in the oven until a constant weight is achieved. The ash content was calculated using Equation (2): Raw fibers weighing 10 g were placed inside a crucible of known weight and placed in a muffle furnace (Cole Parmer model no CBFM516C) at 750 °C for 4 h. The samples were cooled and the residue was obtained as ash.

$$\%A.C = \frac{(A_2 - A_1)}{A_s} \times 100 \quad (2)$$

where A_2 is the weight of the crucible containing ash, A_1 is the weight of the unfilled crucible, A_s is

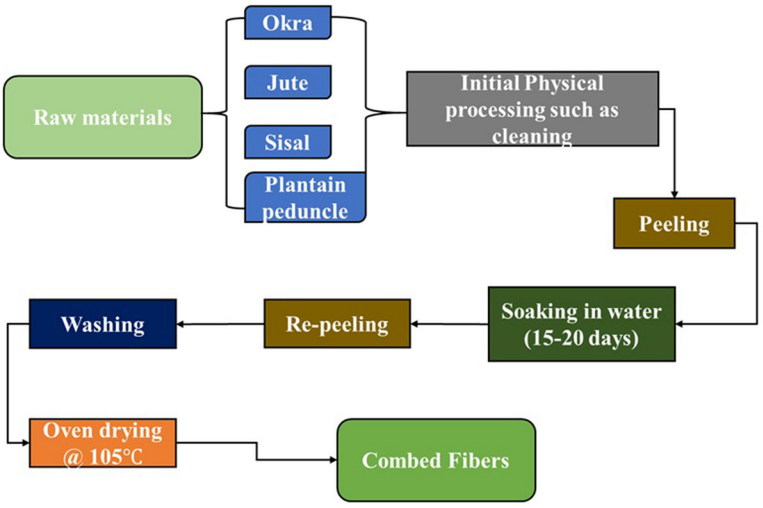

Figure 1. Flow process for fibre extraction.

Figure 2. Extracted fibres (a) okra, (b) plantain, (c) sisal, (d) jute.

the weight of the measured sample, and *A.C* is the ash content of the sample.

2.2.2. Fourier transform-infrared (FTIR) spectroscopy analysis

FTIR analysis was conducted to determine the specific functional groups contained within the fiber samples. This technique identifies and characterizes materials by measuring the absorption of infrared light, which induces molecular vibrations. Each molecule's unique infrared spectrum enables the identification of chemical bonds and functional groups present in the fiber. The fiber samples were combined with analytical-grade potassium bromide (KBr) supplied by Guangzhou Jinjuada Chemical Reagent Company Limited in a ratio of 10:1 after the drying and grinding processes. The resulting mixture was compressed using a press with a force of 10-t resulting in pellet formation. High-resolution optimum spectra were obtained across the spectral region of 4000–400 cm^{-1} using Fourier-transform infrared equipment manufactured by Thermo Scientific Equipment *(*Nicolet IS5, United States). Multiple scans were recorded for the analysis.

2.2.3. X-ray diffraction analysis (XRD)

X-ray diffraction (XRD) analysis is a method for determining the crystalline structure of materials. It involves directing X-rays at a sample and measuring the angles and intensities of the X-rays scattered by the atoms in the crystal lattice. XRD was conducted using an Empyrean device with multicore optics at the intensity of the CuKa radiation wavelength. The fibrous material was cut into smaller portions and subsequently placed within a designated container for analysis. The X-ray diffraction (XRD) instrument was configured with a power of 40 kilovolts (kV) and current of 30 milliamperes (mA). The scanning process was conducted at a rate of 2 degrees per minute (°/min) over an angular range of 5°–80°. This study utilized the empirical technique established by Segal et al. (2016) to ascertain the crystallinity index (CI) and calculate the crystallite size (CS) using Scherrer's formula, which relies on the width of the diffraction pattern observed in the X-ray reflected crystalline section (Manimaran et al., 2019). The cellulose index provides a reliable measure of the proportion of crystalline components relative to the amorphous cellulose inside the fibers.

2.2.4. Thermogravimetric analysis (TGA)

The thermal stability of the fibers was evaluated by measuring the mass loss using a PerkinElmer thermal and differential thermogravimetric analyzer (TGA 4000). The experiment was performed within a temperature range spanning from 30 to 950 °C, at a heating rate of 10 °C/min.

2.2.5. Morphological characterization

Prior to characterization, the samples underwent a process of coating with a thin layer of gold nanoparticles using a small sputter coater (Model: Quorum SC 7620, built in the United Kingdom). This coating was applied to mitigate challenges related to charging and reflection. The images obtained using a Carl Zeiss scanning electron microscope (SEM) model evo10LS-EDAX (Germany) were recorded with a high count per second while employing energy-dispersive X-ray (EDX) technology. SEM was conducted to analyze the surface and cross-sectional morphology of the fibers. The SEM micrographs were subsequently subjected to image analysis to measure the diameter of the fiber bundles over their width. A total of twenty-five readings were obtained for each fiber specimen, and subsequently, the mean and standard deviation were computed.

2.2.6. Single fibre tensile test

The tensile tests of individual fibers were performed using an INSTRON 4411 universal testing machine equipped with a 5 kN load cell, a crosshead speed of 0.5 mm/min, and a gauge length of 50 mm. Each fiber was attached to a piece of cardboard for easy clamping of the fiber on the test machine. Twenty fiber samples were tested to ascertain the tensile qualities of each individual fiber. The mean diameter was obtained using ImageJ software, which analyzed a minimum of 20 measurements for each sample derived from scanning electron microscopy (SEM) micrographs. The experiments were conducted under standard atmospheric conditions, which included a room temperature of 20 ± 2 °C and a relative humidity of 65 ± 4%. These parameters are in agreement with the guidelines outlined in ASTM D 3822. Average ultimate tensile strength, percentage of elongation at fracture, and average Young's modulus.

3. Results and discussion

3.1. Proximate and lignocellulosic contents

The primary constituents of lignocellulosic fibers consist of hemicellulose, cellulose, and lignin (Rowell et al., 2012). According to literature, several variables, including extraction techniques, soil conditions, plant age, and place of origin, affect the chemical composition of cellulosic fibers (Baskaran et al., 2018). These factors have been demonstrated to affect the performance and application of cellulosic fibers. Table 1 presents the chemical compositions of the recently characterized lignocellulosic fibers. The results showed lower cellulose content for plantains (35.5%) and sisal (34.05%) than for okra (68.25%) and jute (66.85%) fibers. The presence of numerous hydrogen bonds among cellulose chains offers the potential to enhance the crystallinity and improve the mechanical characteristics of the fibers (Brum Da Silva et al., 2019). The cellulose content significantly influences the mechanical characteristics of natural fibers. Enhancing the strength and modulus of fibers is a fundamental principle in material engineering. The hemicellulose content of the analyzed biomass samples fell within the range of 13.10–19.60 wt. %, with the exception of sisal, which has a hemicellulose content of 49.4 wt.%. High concentrations of hemicellulose have the potential to induce the breakdown of cellulose microfibrils (Indran et al., 2014). Hemicellulose plays a vital role in processes involving biological and thermal degradation and exhibits a significantly higher water absorption capacity (2.6 times greater than that of lignin). The favorable mechanical and physical characteristics of natural fibers can be attributed to their low density and distinct microstructure. Lignin is a chemical component responsible for plant rigidity. The adhesion process was influenced by the high lignin content found in plantains (21.9%), thereby contributing to their advantageous bonding abilities (Mahieu et al., 2019).

Table 1. Proximate and lignocellulosic contents of the fibres.

Parameters	Okra	Plantain	Sisal	Jute
Moisture (wt.%)	4.00	3.50	8.00	7.50
Ash (wt.%)	16.60	11.79	4.90	1.61
Extractives (wt.%)	12.30	23.0	6.15	8.15
Hemicellulose (wt.%)	17.10	19.60	49.40	13.10
Cellulose (wt.%)	68.25	35.50	33.05	66.85
Lignin (wt.%)	2.35	21.90	11.40	11.90
Relative density	1.1447	0.1899	0.3108	0.3112

3.2. Fourier transform-infrared (FTIR) spectroscopy analysis

The functional group assignments and their corresponding bonding interactions can be determined by Fourier Transform Infrared (FTIR) spectroscopy, as depicted in Figure 3. The results indicated that all four samples displayed similar peaks within the range of 3600–3100 cm^{-1}, with a peak centered at 3493 cm^{-1}. The observed peak can be attributed to the oscillation of the O–H bond and the occurrence of hydrogen bonding within the hydroxyl group (Fan et al., 2012). The peak observed at 2929 cm^{-1} corresponds to the vibrational band associated with the C–H bonds present in both the CH and CH_2 groups within cellulose and hemicellulose (Fan et al., 2012). The shoulder observed at 2345 cm^{-1} was attributed to the stretching vibration of the carbon-nitrogen (N) bond. The observed peak at 1645 cm^{-1} could potentially be attributed to the presence of water within the fiber. The peak observed at 1422 cm^{-1} corresponds to the CH2 symmetric bending mode, which is characteristic of cellulose. The spectral peak observed at 1235 cm^{-1} can be ascribed to the vibrational mode linked to the stretching of the carbon-oxygen (C–O) bonds within the acetyl functional group present in the hemicellulose molecule. The prominent peak observed at 1050 cm^{-1} is attributed to the stretching vibration of the CO and OH groups, which are characteristic of polysaccharides found in cellulose. While the spectra exhibit similarities, there are certain variations, with the most significant one ascribed to the heightened intensity of the symmetric in-phase ring stretching vibrations of cellulose and hemicelluloses.

3.3. X-ray diffraction analysis (XRD)

The crystalline structures of all four types of fibers were examined by X-ray diffraction analysis using CuKα ($\lambda = 1.54$) radiation and a graphite monochromator. The diffraction intensities were measured in the range of 5–70°. The X-ray diffraction (XRD) patterns of all the fibers are shown in Figure 4. The primary constituents of plant fiber cell walls are cellulose, hemicellulose, and lignin. Cellulose is composed of both amorphous and crystalline regions, whereas lignin and hemicellulose are amorphous. X-ray diffraction (XRD) analysis indicated that a prominent crystalline peak was observed at approximately $2\theta = 20$–22°, exhibiting varying degrees of crystallinity. Additionally, an amorphous peak was detected within the 2θ range of 15.98–16.62°. According to previous reports, an increase in the presence of amorphous cellulose, lignin, and hemicellulose within the fibers leads to a reduction in the peak intensity and a blurred appearance in the diffractograms. This phenomenon can be attributed to the amorphous nature of the constituents. Nevertheless, the diffractograms exhibited a more distinct and well-defined peak when the plant fiber contained a higher concentration of crystalline cellulose, as seen in the figure. The crystallinity index (CI) and crystallite size (CS) values calculated for the fibers are shown in Figure 5. Okra presented the highest values (66.08%), followed by sisal (41.20%), plantain peduncle (54.24%), and jute (54.69%). The tensile properties of the fibers are improved with higher crystallinity because the cellulosic chains become more regularly aligned as the crystallinity increases (Dalmis et al., 2020). Therefore, higher crystallinity when used as a reinforcement aids in the creation of high-strength composites. The resistance of natural fibers to thermal degradation also increases with the

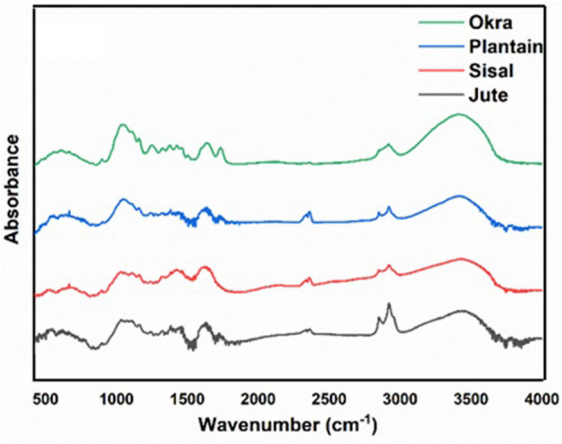

Figure 3. FTIR spectra of the fibres.

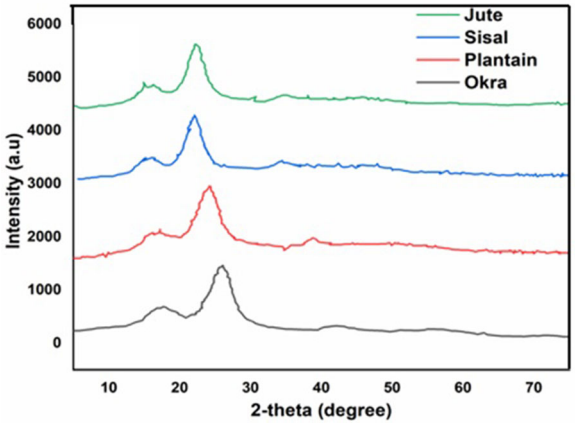

Figure 4. XRD spectra of the fibres.

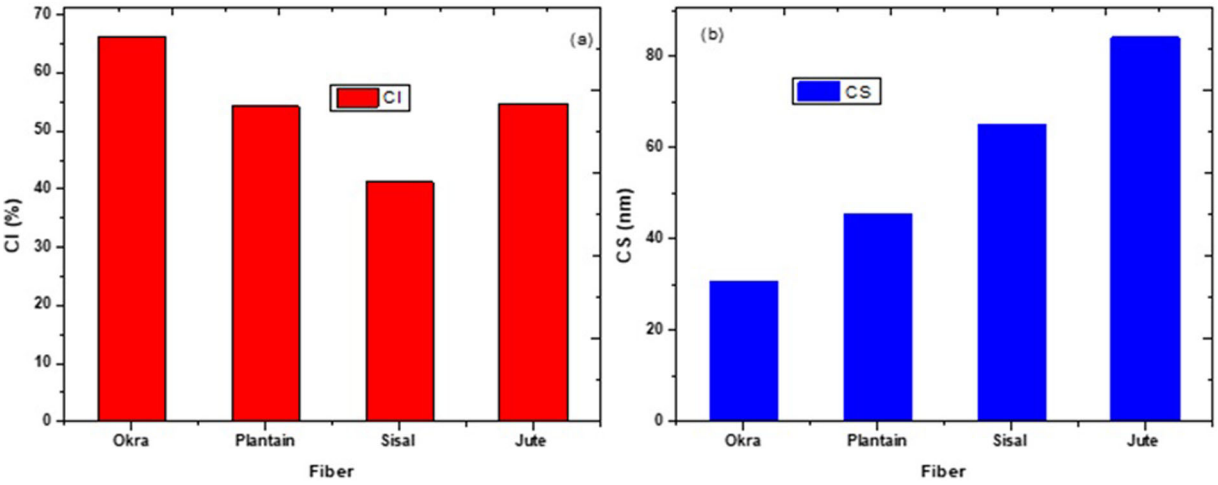

Figure 5. Crystallinity index and crystal size of studied fibres.

Table 2. Weight loss of fibres with respect to temperature.

Samples	Okra			Plantain			Sisal			Jute		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
OnT	25	290	368	27	293	371	22	289	371	27	281	343
MaxT	110	368	424	100	371	446	105	357	416	100	343	408
Mass loss	3.58	29.91	42.6	8.71	23.88	47.73	3.9	23.08	39.16	6.1	20.45	29.23

OnT : onset temperature (°*C*); MaxT: maximum temperature (°*C*); R1: region 1 begins; R2: region one end, region 2 begins; R3: region 2 ends, region 3 begins.

crystallinity level (Adeleke et al., 2022). Okra has the lowest CS; hence, it exhibits a very low water absorption property compared with the others.

3.4. TGA/DTA analysis

This investigation is necessary to ensure that the natural fibers do not undergo any degradation when exposed to these high temperatures and to optimize the overall properties of the fibers in the composites.

Table 2 shows that degradation occurs in three stages. The initial stage occurs within the temperature range of 25 and 110°C, resulting in a mass loss that signifies the loss of moisture and other volatile material from the fibre; a moderate mass loss was observed between 281 and 371°C at the second stage which is attributed to thermal depolymerization of hemicelluloses, and finally, at above 340°C, a maximum weight loss occurred due to the breakdown of cellulose and lignin with ash as residue, constituting the third stage of mass loss. These results are supported by the DTA curve in Figure 6(a–d), wherein the maximum decomposition rates for the weight losses are displayed. The maximum degradation temperatures of the fibres are above 400 °C. This could also be due to the high crystallinity index of the fibres. This is higher than values obtained for other fibres such as bamboo (321°C), kenaf (309.2°C), hemp (308.2°C) and jute fibres (298.2°C) (Lakshmaiya et al., 2022). Cellulose is composed of both crystalline and amorphous components. The amorphous component degrades faster than the crystalline component, which has greater heat stability. Highly crystalline cellulose begins to break down until hemicellulose is destroyed, which often begins at a higher temperature, around 320°*C*. Furthermore, due to the molecular structure (aromatic rings) of lignin, the degradation of lignin entails a wide range of decomposition temperatures (Watkins et al., 2015). It is more difficult to disintegrate than hemicellulose and cellulose, and it is the chemical that provides rigidity to plant materials. The result indicates that the fibres are a suitable material for use as reinforcement in industrial applications that require high-temperature tolerance such as automotive parts.

3.5. Scanning electron microscope

The SEM images depicting the fibers are shown in Figure 7(a–d). The visual representation illustrates clusters of discrete cellular units consolidated through the presence of lignin-enriched, relatively fragile intermolecular bonds. The surface of the fibers is rough and has longitudinal ridges, potentially improving the mechanical interlocking with the polymer matrix. Natural fibers have a rough, uneven

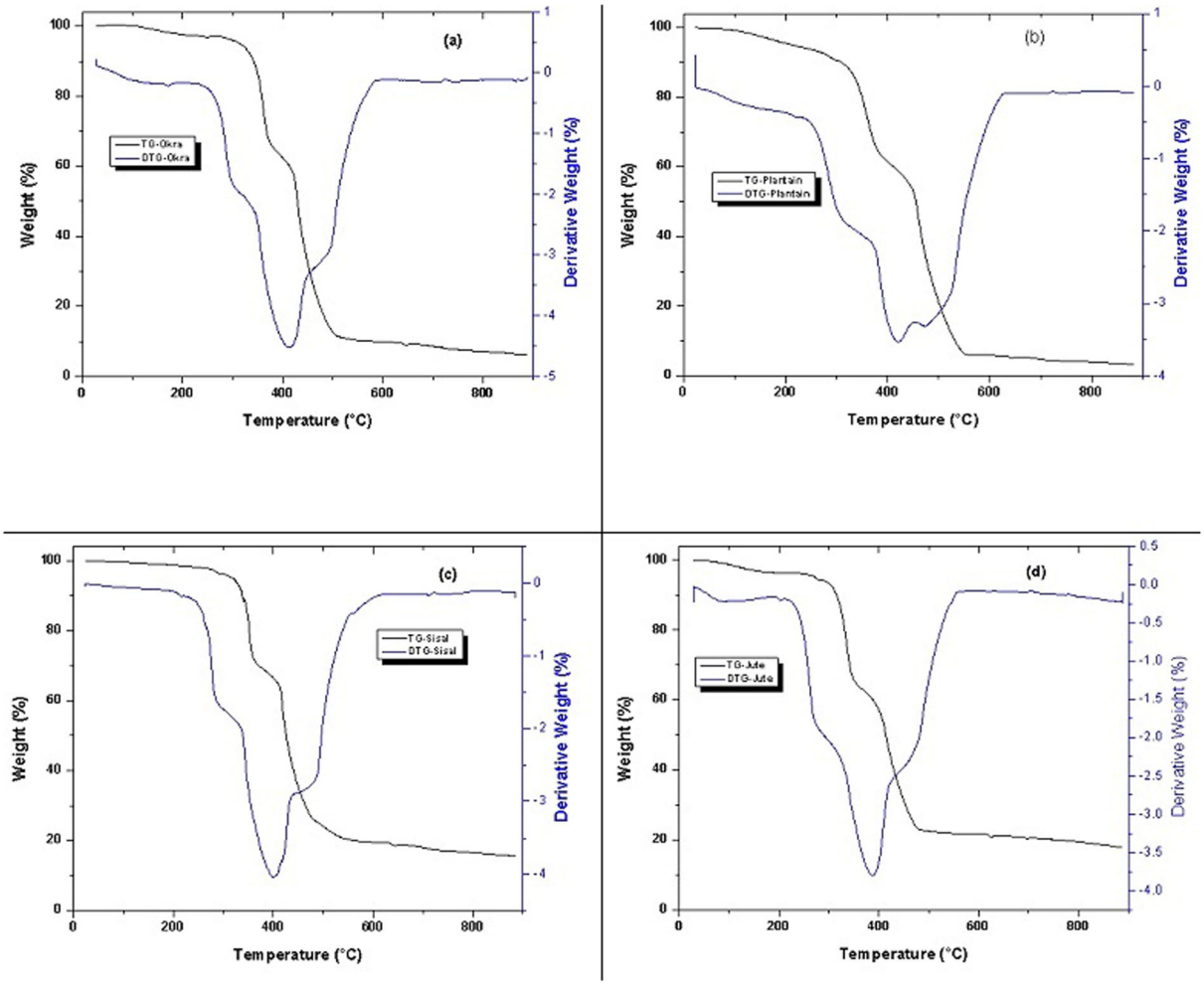

Figure 6. DTA/TGA results (a) okra (b) plantain (c) sisal (d) jute.

surface that helps them adhere well to the matrix within a composite structure. The degree of surface smoothness or roughness of a fiber affects its compatibility with the chemicals that interact with it, such as resins. Rough surfaces produce more anchorage points, which improve the mechanical interlocking between the fiber and resin. Contaminants including hemicelluloses, lignin, and wax were observed. The identification of white spots on the fiber surface indicates the presence of contaminants or localized damage resulting from the handling procedure. These observations were similar to those reported by Hashim et al. (2017).

3.6. Single fibre tensile test

The mechanical characteristics of the studied fibers are shown in Figure 8. The tensile strength of all the fibers was calculated to be between 111 and 294 MPa to 1.41–3.23% of the elongation at fracture. An average Young's modulus value was obtained between 2.73 and 26.02 GPa and fibre diameters of between 140.14 and 319.33 μm. The mechanical qualities of fibers are mostly determined by their chemical composition, particularly the amount of cellulose. The mechanical strength of natural fibers is primarily attributed to their cellulose content, which possesses distinct characteristics, including a high degree of polymerization and linear orientation (Manimaran et al., 2019).

4. Conclusions

The selected fibers extracted from okra stem, plantain peduncle, sisal, and jute plants were obtained from different parts of Nigeria and characterized. FTIR and proximate analyses were used to determine the primary chemical compounds of the fibers, such as cellulose, hemicellulose, and lignin. The results obtained from the chemical composition analysis show variation in the composition of the fibres; the cellulose percentage of the biomass samples analysed fell within the range of 33.05 to 68.25 wt % with okra stem fibre having the highest cellulose

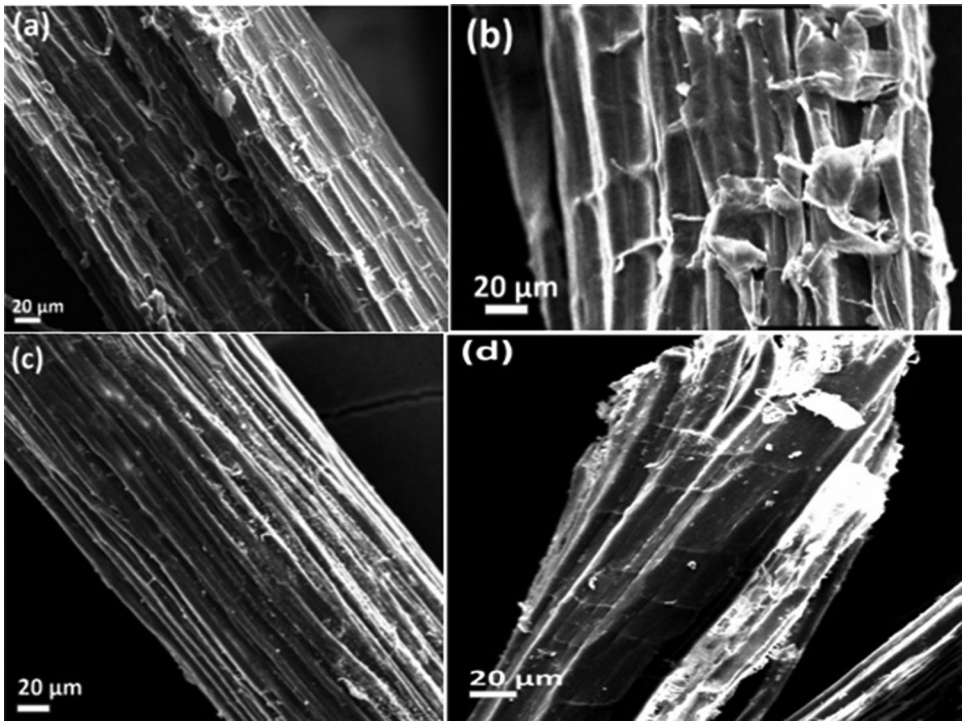

Figure 7. SEM of the fibres ×1000 magnification: (a) okra (b) plantain (c) sisal (d) jute.

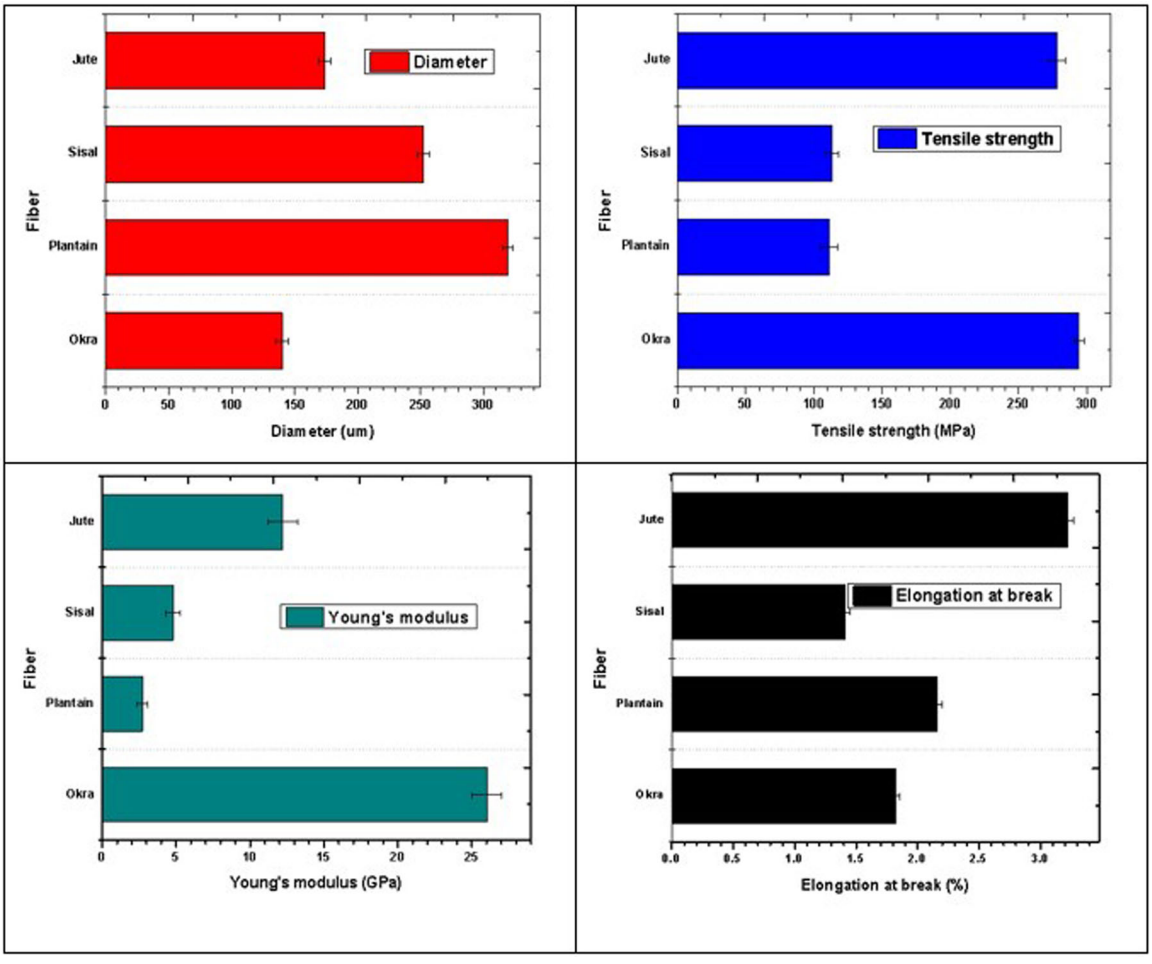

Figure 8. Mechanical properties of the fibres studied.

content of 68.25 wt. % which could be attributed to the species of okra used in this study. Thermal analysis revealed that the fibers were stable at temperatures as high as 280 °C. The tensile strength values obtained for all the fibers ranged from 111 to 294 MPa, with elongation at fracture between 1.41 and 3.23%. An average Young's modulus value was found to be between 2.73 and 26.02 GPa, and fiber diameters ranged from 140.14 to 319.33 μm, making the fibers suitable for use in lightweight composite applications such as automotive interiors, particle boards, roof tiles, and ceiling boards. This study also suggests that the qualities of these fibers make them appropriate for a diverse array of applications, potentially enhancing the utilization of locally sourced fibers in Nigeria. Also, these fibers are biodegradable and can serve as alternatives to plastic and plastic-reinforced composites, which contribute to environmental pollution.

Acknowledgment

The authors appreciate the management of the African University of Science and Technology (AUST), Abuja, for providing some of the equipment used in this study. This research was not supported by any funding agency.

Author contributions

ENAF, GOI: conceptualization, methodology, data curation, writing – original draft. **PAU, IIO**: writing – review and editing, software. **SJ, AAA:** Validation, supervision, writing –review and editing. **PP**: writing – review and editing, project administration, software. **APO:** Resources, visualization. **RV**: writing – original draft, writing –review and editing. All authors have read and approved the final version of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [RV], upon reasonable request.

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