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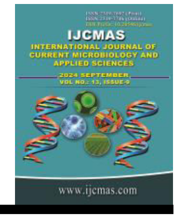

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A Comprehensive Study on Physicochemical, Mechanical Properties, and Characterization of Jute Fiber

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Jute is a natural fiber occupying second place in economic importance and industrial applications only after cotton. Jute fiber is one of the most common biodegradable natural fibers which successfully replaced the synthetic and glass fibers. Jute is a long, soft, shiny bast fiber that can be spun into coarse, strong threads. The present experimental research is done to investigate the physicochemical, mechanical properties, and characterization of Jute fibre. It is observed that the jute fiber has cellulosed content of 54.81% and lignin content 12.4%. Tensile strength of the fiber is found to be 31.14 cN/tex with fiber elongation of 1.9%. These are important properties which effect on the functionality and utility of the end products. The fiber exhibits functional groups such as hydroxyl groups, aldehyde, stretching aromatic ester, primary alcohol, alkene, and halogen compounds in the Fourier Transform Infrared (FTIR) analysis. Scanning Electron Microscopy (SEM) spectra reveals fragile fracture with the presence of gummy and natural impurities as well as the outer epidermal layer of jute fibers. Jute fiber has several attractive advantages over synthetic and glass fiber like as low processing cost, low density, stiffness easily available, excellent mechanical properties, and low production energy required Jute fiber is widely used now-a-days both in the industry as well as in the manufacture of various value-added materials for domestic use.

Introduction

Biobased fibers, also known as natural fibers, are derived from natural sources and are increasingly gaining attention in various industries due to their preferable superior characteristics, as they are biodegradable, more affordable, and advantageous which have a lesser environmental effect than synthetic fibers (Shahinur *et al.,* 2015; Thiruchitrambalam *et al.,* 2012). Amongst all natural fibers, jute is one of the cheapest, economical and the second most important biobased fiber after cotton in terms of usage, worldwide consumption, production, and availability which is obtained from the skin or bast of the jute plant (Britannica, 2023). The jute plant belongs to the *Corchorus* genus of flowering plants, which are members of the *Malvaceae* / *Tiliaceae* family (Azizo, 2019; Wikipedia, 2021). It grows to an average height of 8 to 12 feet (3 to 3.6 meters) with a cylindrical stalk (Textile coach, 2021). Colour of jute fiber varies from yellow to brown to dirty grey and possesses a natural silky lustre. Generally, jute fiber is coarse and harsh to feel. Jute is a type of lignocellulose fiber, which is mostly made up of cellulose, lignin, and pectin, completely recyclable, biodegradable, and environmentally friendly that has high tenacity, breathable with low extensibility and low crimps, dyeable, and most adaptable natural fiber (Jitaan, 2021; Vaishnavi and Krishnaveni, 2022).

The low extensibility, softness, high tensile strength, and adaptability of jute fiber make it a popular raw material for a variety of nonwoven textile applications including bags, hessian, sacking, canvas, twines, packaging, and agricultural uses. Jute is also called the “golden fiber” and is taken as the fiber of the future. In many situations, the biodegradable properties of jute make it an appropriate material for replacing synthetic materials (Duan and Yu, 2015; Mishra and Biswas, 2013).

India is a major consumer of jute due to its affordability, strength, softness, minimal carbon footprint, luster, and fiber consistency. Most of the world’s jute is produced in India, Bangladesh, China, and Pakistan. The Ganges River Delta, which includes parts of Bangladesh and India's Bengal area, is specifically responsible for 85% of the world's jute production because of its rich alluvial soil, ideal temperature, and ample rainfall (Shelar and Narendra Kumar, 2021; Sewport Support team, 2023). The Major varieties of jute are white Jute and Tossa Jute, and fibers are extracted by a retting process facilitating to ferment the non-cellulosic material binding of fibers and remove it by washing in water. Colour of jute fiber varies from off white, yellow to brown to dirty grey. The cultivation and use of jute fiber not only help us in ecological balance but also provide employment to the rural people in countries like India and Bangladesh where jute is abundantly grown (Sengupta, 2004; Kiron, 2021).

Although jute plants produce relatively long fiber, the fibers are uniformly smooth, and glossy and have little stiffness and moderate draping. Jute products often have a distinct and appealing aesthetic which can be desirable in fashion and home décor. The uniformity of the fiber obtained from the jute plant makes them highly desirable commercially (Maity *et al.,* 2012; Biju’s, 2023). Jute fiber has been extensively used in reinforcement composites in automotive applications, spun lacing, needle-punched products in civil engineering, cellulose applications, and automotive applications (Santos *et al.,* 2021; Britannica, 2023). Jute is also called the 'brown paper bag' as it is the most used product in gunny sacks to store rice, wheat and grains (Wikipedia, 2021). Considering the benefit and potentiality of the jute fibers, the present topic is taken to gather a clear understanding of its physico- chemical, mechanical properties and characterization of the fiber.

Materials and Methods

Collection of Materials

The selection of natural fibers for research is categorized as per availability in particular region. The raw material is the key factor in designing the material. The selection of raw materials affects the function and quality of the product (Dhanabalan and Karthik, 2013). For the present study, Jute plants (Tossa) were collected from Assam.

Chemical and Solvents

For chemical analysis, different analytical reagent grade chemicals such as sulphuric acid, ether, hydrogen chloride, alcohol-benzine, sodium hydroxide, acetic acid, sodium sulphite etc were used in different stages of the testing.

Morphological Characteristics of Jute Plants

The average length, weight, and width of ten (10) stems of jute plants were measured individually with the help of a measuring tape and the results were recorded.

Optimization of Extraction process of Jute fiber

After harvesting, the stems of the jute plant are made into small bundles and tightened together. Then it was submerged in water. The fibers were checked regularly every 3 days to ensure that the fibers were softened completely for easy separation from the stalk. The retting process took about 20 days. The fibers were separated from the stem and washed thoroughly in water. Finally, the fibers were spread out for drying in sunlight for about 2-3 days and kept ready for further processing.

Chemical Analysis of the Jute Fiber

The chemical composition of the fiber was assessed as per established standard methods. The cellulose, alpha cellulose, and hemicellulose content were determined following TAPPI standard method T-17m-555 (1980). Lignin content was measured according to TAPPI standard method T-13 m-54 (1980). The ash content of the fiber was analysed using TAPPI standard method T-211cm-86 (TAPPI, 1980). Crude fat or wax content was determined using a Soxhlet apparatus as per BIS: IS: 199, 1973. Moisture content of the fiber was evaluated following TAPPI standard method T-264cm. The mean values of the analysis were determined and recorded.

Physical and Mechanical Analysis of Jute Fiber

The physical properties of jute fiber were determined by following different standard testing procedures and the average values of the observations were recorded. The average length was measured as per the ISI 6653-1972(48) method. The diameter of the fiber was determined based on testing standard BS-3085 No:11. Fiber fineness (tex) was measured following standard ASTM D 1577-01 and recorded. The density of pineapple fiber was determined based on (ASTM, 1970) and recorded in grams per cubic centimetre (gm/cc). To determine the whiteness index of the fiber, an instrument known as "Premier color scan" was used and measured based on 10/deg/D65/Hunter, standard methods. Tensile strength and elongation were tested as per the Test method ASTM D 3822. The wicking height of the fiber was calculated based on the Test method AATCC, 1967. These comprehensive tests provide a detailed overview of the physical characteristics of the fibers, crucial for understanding their suitability and performance in various applications.

Characterizations of Jute Fiber

Fourier Transform Infrared Spectroscopy (FTIR) analysis of finely crushed jute fiber was evaluated in Miracle 10ZnSe Infrared Spectrum Analyzer. Field Emission Scanning electron microscopy (FESEM) and Energy Dispersive Spectroscopy (EDS) test was performed using a high-resolution scanning electron microscope TESCAN MIRA 3 XMU to observe the microstructure and chemical components of fibre. Thermogravimetric Analysis (TGA) and Differential Thermogravimetry (DTG) was analyzed to investigate the thermal stability of the fiber using model TG/DTA-EXSTAR/6300 (Thermo Gravimetric Analyser). X-ray Diffraction (XRD) was performed to identify the crystallinity of the fiber. X-ray diffractograms were collected using a sample holder mounted on a diffractometer with monochromatic CuKα radiation ($\lambda = 0.15418$ nm), scanning values of 2Ɵ ranging from 10° to 80° and operated under high voltage.

The crystallinity index (C.I) and percentage of crystallinity (Cr %) of fibers were calculated by using the peak height /intensity method (Segal *et al.,* 1959) and relevant equation (1) and (2).

$$C.I = \frac{Ic - Iam}{Ic} \quad \ldots(1)$$

$$Cr\,(\%) = \frac{Ic}{Ic + Iam} \times 100 \quad \ldots(2)$$

Where 'Ic' is the maximum intensity of the peak which corresponds to the crystalline fraction at 2Ɵ angle and 'Iam' indicates the intensity of diffraction of the amorphous region at 2Ɵ angle.

Results and Discussion

Morphological Characteristics of Jute Plant

The jute plant collected for the study were evaluated for morphological characteristics such as average height of the plant, weight and length of the stem, and the girth of the stem at three different portion such as bottom, middle, and top. The average height of the jute plant is found to be 336.4 cm, and average weight without leaf is measured approximately 182.3 gms. The jute plant grows to heights between 2 m and 3.5 m with stalk diameters ranging from 2 cm to 3 cm (Cutter, 2008). Unlike flax and hemp, jute plants are grown entirely for its fibers which are between 1.5 and 3 m in length. The average length of jute stem measured 315 cm., and the girth of stem measured at three portions are found to be 8.4cm at bottom, 7.6 cm in the middle and 3.4 at the top portion.

Optimization of Extraction of Jute Fiber

The yield of jute fiber was observed 9.2% in day nine because of the fibers are not softened to remove from the nonfibrous material. The yields of the fibers were 10.5%, 11.7%, 11.3%, and 11.1% in 14, 17. 20, and 23 days respectively. The fibers on 20th day were very soft shiny as well as clean. Therefore, the fibers were taken for the study. The graphical presentation of the yields with respect to days is given in Fig.1

Chemical Analysis of the Jute Fiber

The data presented in Table 1 highlights the chemical composition of the jute fiber of the present study with other plant fibers. The jute fiber has cellulose content of 54.81% hemicellulose of 22.2%, alpha cellulose of 45.07%, lignin 12.4%, ash content 0.292%, Fat 0.103% and moisture content of at 11.7%. More or less similar values of (60-63) cellulose, (21-24) % of hemicellulose, (12-13)% lignin, (0.7-1.2)% ash, and 0.16% fat contents were observed by previous study (Ray, 2023). Chemical composition is one of the important elements, especially cellulose and lignin that influence the physical, mechanical, and thermal properties of natural fiber (Widyasanti *et al.,* 2020). Generally, higher mechanical strength of natural fibers was achieved due to higher cellulose content and cellulose microfibrils aligned more in the fiber direction (Johansson *et al.,* 2012). Higher lignin content produces a stronger fiber as it lends a rigid structure, holding the fibrils together, and imparting stiffness to the cell wall, thus providing a protective barrier for cellulose and fiber's resistance to decomposition (Patra, 2012; Geng *et al.,* 2022). Moisture content is another critical factor influencing natural fiber's dimensional stability, electrical resistivity, tensile strength, porosity, and swelling behaviours (Cottrell *et al.,* 2023).

While considering the cellulose 54.81% content of the current study of jute fiber, it is comparable with other vegetable fiber reported by other scholars ranging from 45% to 78% cellulose. However, hemicellulose 22.2 % content is greater than other fiber. In the case of lignin content 12.4%, it is within the range of 7.25% to 12.5% and ash content 0.292% and fat content 0.103% is lower than other fiber contents of other vegetable fiber reported by another researcher. Thus, we can conclude that the chemical composition of jute fiber is more or less similar than other chemical component of vegetable fibers reported by other research scholars. The above results show that the fiber has high cellulose, alpha-cellulose, hemicellulose, and lignin contents which tend to give strength and compactness in the fiber and thus can be utilized for rope making, dusters, doormats, carpets, filter papers, and packaging materials.

Physical and Mechanical Properties of Jute Fiber

The physical and mechanical properties of the jute fiber were determined and datas are given in Table 2. The length of jute fibers varies from87cm-310cm. It is one of the important properties of the fiber. Fiber diameter was measured to be 0.0065 mm whereas fiber fineness was calculated as 3.048tex which denotes the relative thickness of the fibers and impacts their overall performance and suitability in textile applications. Again, while observing the density of jute fiber, it is found to be 1.5 gm /cm3 providing insight into its compactness and mass per unit volume.

When evaluating fiber quality, the length, fineness, and strength are deemed the most vital indicators (Geng *et al.,* 2022). In addition, the fiber fineness is the relative size of the diameter expressed in terms of the weight of the unit length that affects the textile fibers' overall performance, appearance, suitability, and feel of the final textile product (Gudayu *et al.,* 2022). The Whiteness index, of jute fiber is getting lower Hunter scale (52.072) when compared to the standard whiteness index of jute fiber (54.053). The fiber fineness, length, and strength are three of the most important indexes to evaluate fiber quality (Gudayu *et al.,* 2022). The wicking height of the jute fiber was measured as 1.18cm/min. Higher wicking values show greater capability for transporting liquid water and are crucial for applications requiring moisture absorption and regulation, such as textiles used in clothing and upholstery.

From Table 2 it is also observed that the tensile strength of jute fiber was found to be 31.14 cN/tex and elongation to be 1.9 %. Tensile strength plays a crucial role in determining the overall quality, durability, and performance of textile and the kind of application it can be used for Adugna Ayalew and Fenta Wodag (2022). Fiber diameter and aspect ratio (length-to-diameter ratio) are essential parameters that affect the tensile strength and other mechanical properties of the fiber and its products (Gudayu *et al.,* 2022).

When comparing the physical properties of jute fiber with other natural fibers, the length, and density of the fiber are greater than other vegetable fibers. However, diameter 0.0065mm, fiber fineness (3.048tex), tensile strength 31.14cN/tex, and elongation 1.9% occurred within the range of values reported for other vegetable fibers by research scholars.

Visually, jute fiber appears reddish in colour, soft with little rigidity and flexibility, and softer than other natural fibers. From the above result, we can infer that the jute fiber is one of the longest fibers among the plant fibers and comparable to other vegetable fibers and can be utilized for many applications such as insulation, cement bags, sacks, and various geotextile and industrial products coverings of outdoor furniture.

Characterization of Jute Fiber

Fourier Transform Infrared (FTIR) spectroscopy of jute fiber

FTIR measurements were performed on jute fiber to find out the presence of chemical functional groups at different intensities. It is apparent from Fig 2 that the FTIR spectra of jute fiber revealed a medium vibration and highly absorbent and stretching spectrum peaks at 3680 cm-1, 3560 cm-1, 3200 cm-1, 1720 cm-1, 1519cm-1, 1245 cm-1,1045 cm-1, 880 cm-1,680 cm-1, 524.64 cm-1 and 455.20 cm^{-1}. The strong O-H stretching absorption values are found at the peaks at approximately 3400cm-1 to 3200cm-1 which represents the presence of hydroxyl groups in the spectrum due to the presence of carbohydrates and polyphenols. The broad peak 1720 cm^{-1} shows a corresponding C=O stretching double bonded functioning groups of aldehydes in the spectra which may be associated with the vibration of water molecules adsorbed by the Consistent. The spectra between the peak 2800 cm-1 to 1400cm-1 presented a highly stretching and highly absorbent band that reflect the aromatic ring vibration and CH3 asymmetric deformation of lignin. It is also revealed from the fig that the 1245 cm-1 peak shows a group of C-O stretching aromatic ester group. Again, broad peak 1045 cm-1 shows the presence of C-O stretching functioning group of primary alcohol and is characterized as polysaccharide in cellulose. The peak 880cm-1 attributed a medium vibrating spectra having a C-C bending strong group of alkenes. The peaks between 680cm-1 to 455.20 cm-1 are characteristics of C-Cl, and C-I stretching vibration of Hello compounds such as chloro compound, and Iodo compound respectively. Based on this information, it can be inferred that jute fiber contains functional groups such as hydroxyl groups, aldehyde, stretching aromatic ester, primary alcohol, alkene, and halogen compounds. A similar observation was reported by Duan and Yu (2015).

Scanning Electron Microscopy (SEM) of Jute Fiber

The surface topology of jute fibers was examined through SEM and micrographs were presented in Fig.3.3. The SEM image of jute fiber is exhibited fragile fracture with the presence of gummy material and protrusions on the surface due to the presence of natural impurities and non-cellulosic components, as well as the outer epidermal layer of jute fibers. There are deposits and derbies of the fiber surface obscuring the fibril structure and seems to be peeling off the surface and developing of longitudinal crack on the surface of the fiber so that the surface morphology appeared rough and textured with evidence of random micropores.

In some portions, the fiber shows nodes in longitudinal direction along with remarkable constrictions in the cell wall. The longitudinal micro-morphology of jute fibers and revealed that raw jute fibers were cemented with gummy materials, resulting in a coarse and irregular surface. Similar characters were investigated by Jabbar *et al.,* (2016); Duan and Yu (2015); Mishra and Biswas (2013).

Energy Dispersive X-ray Spectroscopy (EDX)of jute fiber

The figure 4 exhibits that Jute fiber has major components of carbon 52.27%, and oxygen 47.73%. In a previous study Salem *et al.,* (2020) evaluated marginally similar values of carbon 54.53%, oxygen 40.15% and silicon 0.93% elemental component of jute fiber. It is also state that oxygen and carbon are the most dominant elements in all EDX spectra of lignocellulose fiber because they are the main elements that make up the fiber structures (Yusof *et al.,* 2023; Zidi and Jaballi, 2023). Thus, the observed value indicates that jute is also a lignocellulose fiber.

Thermogravimetric Analysis of Jute Fiber

The decomposition behaviour of jute fiber shown in Fig.5 affirmed that from room temperature to 180°C, 9.5% of the mass of jute fiber decreased due to evaporation of moisture present in the fiber.

After the removal of moisture, the degradation process began in the cellulose, hemicelluloses, and constituents from 180°C to 390°C. Mass begins to decrease greatly due to the high thermal degradation of the main constituent of jute fiber. Between 390°C to 500°C, the rate of mass reduction decreases and a total mass loss of 73% of the original mass occurs at this stage. Lignin degradation is responsible at this temperature as its stability in thermal stability is greater than other constituent of jute fiber.

Table.1 Chemical analysis of jute fiber and few other plant Fibers

Fiber	Cellulose (%)	Hemi cellulose (%)	Alpha-cellulose (%)	Lignin (%)	Ash (%)	Fat (%)	Moisture (%)	Reference
Jute	54.81	22.2	45.07	12.4	0.292	0.103	11.7	Current study
Pineapple	55-66	15.34	--------	8-12	0.95	0.96		P. Pandit *et al.,* (2020) Hazarika D., *et al.,* (2016)
Snake plant	78.63	20.1	---------	7.85	1.49	0.16	7.85	M. Gopi Krishna *et al.,* (2020)
Roselle	56.25	11.50	20.23	7.25	2.08	0.50	7.4	Tamta M (2020)
Kenaf	45-57	8.13	--------	12.5	2.5	0.8	6.2-12	Kirom M I (2021

Table.2 Analysis of Physio-mechanical properties of sisal fibre with other plant fibers

Fiber	Length (cm)	Diameter (mm)	Fiber Fineness (tex)	Density (gm/cm^3)	Tensile Strength (cN/tex	Elongation (%)	Whiteness Index (Hunter scale)	Wicking Height cm/min	Reference
Jute	87-310	0.0065	3.048	1.5	31.14	1.9	52.072	1.18	Current study
Pineapple	10-90	0.003-0.008	2.5-5.5	1.543	30-40	2.4-3.4	60.00		P. Pandit *et al.,* (2020) Hazarika, *et al.,* (2017)
Snake plant	76		5.8	1.41	33.98	10.13			Devaki E & Boominathan S (2021
Roselle	122	0.014	3.5	1.49	30.0	1.59		1.3	Tamta M 2020
Kenaf	4-30			1.2		2.5-3.5			Fiore, *et al.,* (2015)

Table.3 Variation of crystalline index and crystalline percentage of Jute fiber

Fiber	Maximum Intensity (Ic)	Angle(2ϑ) at (Ic)	Maximum Intensity (I_{am})	Angle(2ϑ) at (I_{am})	Crystallinity Index (CI)	Percentage of Crystallinity (%)
Jute	1770	23.0	1000	16.0	0.435	63.90

Figure.1 Jute Plant Parts

		
Figure.a Jute Plant	Figure.b Jute Stem	Figure.c Jute Fiber

Figure.2 Yields of jute fiber

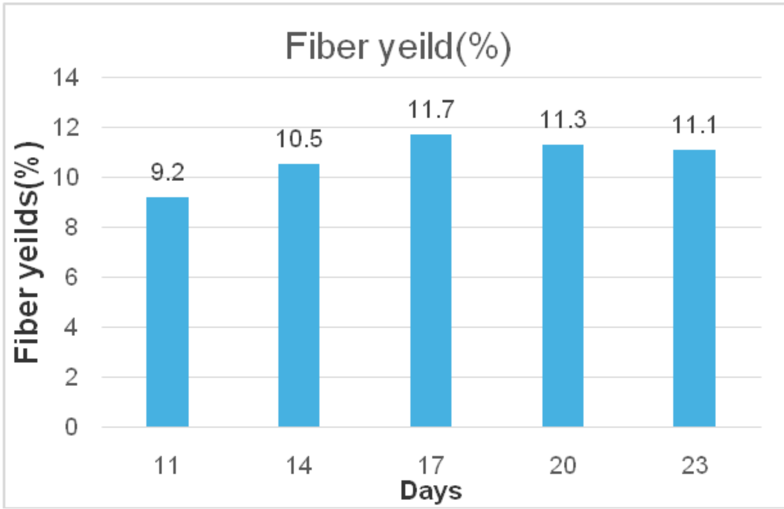


Figure.3 FTIR spectra of jute fiber

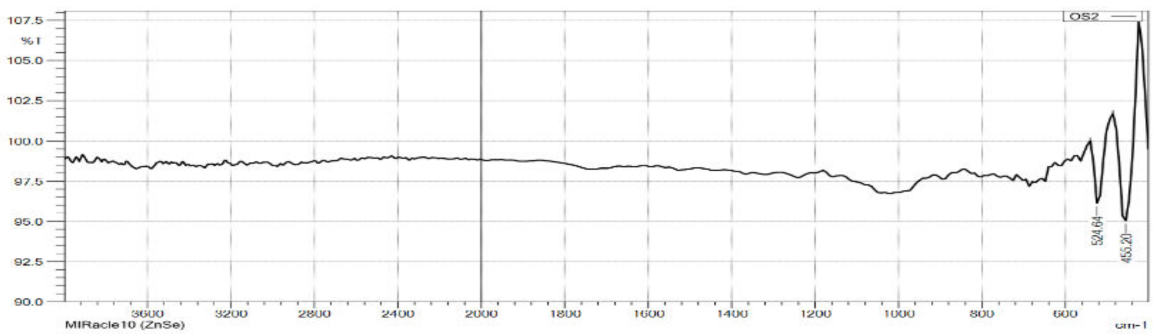


Figure.4 Scanning Electron Microscopy (SEM) images of jute fiber

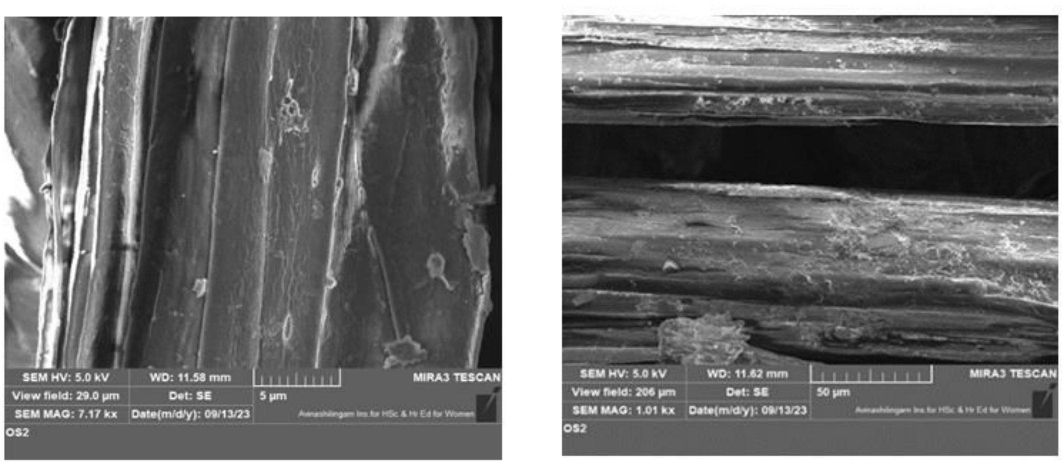


Figure.5 EDX spectra of Jute fiber

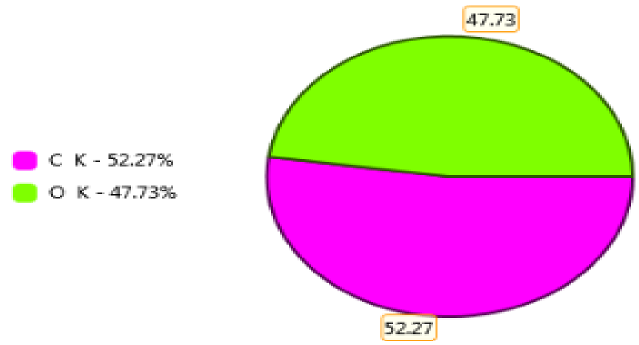


Figure.6 TGA (Blue curve) and DTG (Red curve) curves of jute

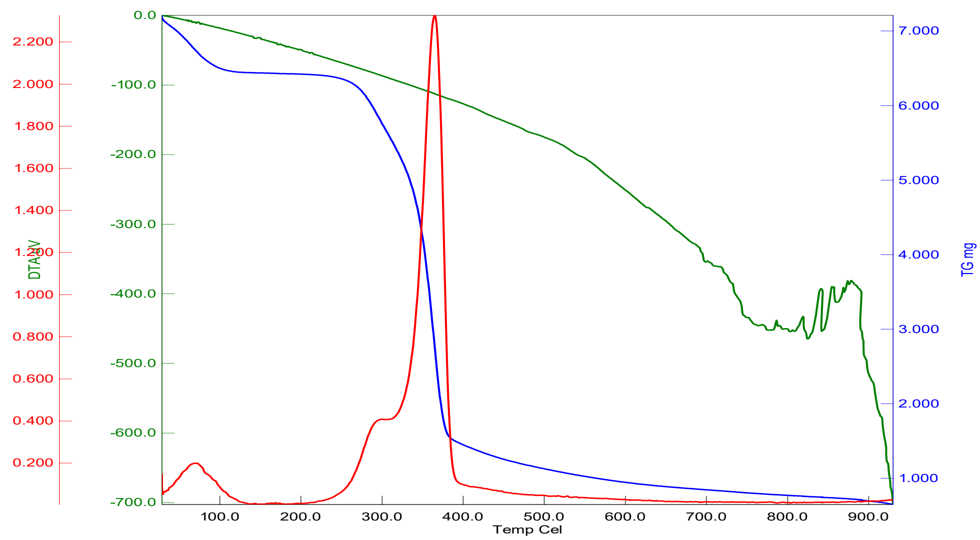
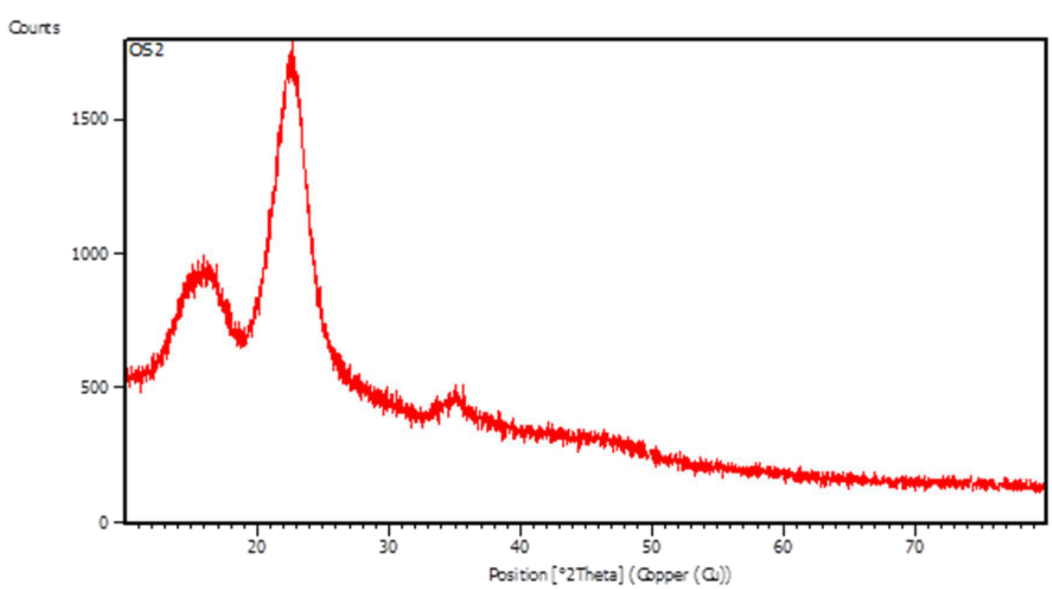


Figure.7 X-ray diffractograms of jute fiber



It is reported that Lignin is generally the hardest component present in the cell wall which will be highly stable and hence the degradation takes place at the higher temperature range of 350°C to 500°C (Chandrappa and Kamath, 2022). In the next stage, the degradation remains continue in a slow rate till to reach a stable mass at around 950^0c with a mass reduction of 6.3% of the total weight. After completing the analysis, a total mass loss of 90.99% of the total weight occurred and only 9.01% mass residue is observed. Derivative Thermogravimetry (DTG) curve of jute fiber shows the first peak at 70^0c which indicates the removal of moisture from the jute fiber, a lower temperature peak at around 290^0c for jute fiber, which was due to the decomposition of hemicellulose. Furthermore, a large peak at a temperature of around 380^0C was due to cellulose and lignin decomposition. Similar results in the DTG curve of jute state that the peaks below 100^0C are attributed to loss of moisture absorbed by the fibers and strong sharp peaks at around 365 °C are due to the degradation of cellulose (Jabbar *et al.,* 2016).

X-ray diffraction (XRD) analysis of jute fiber

Jute XRD analysis was done to investigate the crystallinity and amorphous structure of the fiber. Based on Figure three peaks were observed at 2θ = 16° and 23.0°, and 35^0. which indicates the presence of typical cellulose I form and alignment of hemicelluloses, lignin, and impurities of cellulose molecules. Similar peaks at 2 θ=16°, 22.6^0 and 35^0 are also investigated in another study (Duan and Yu, 2015). The diffraction intensities at the diffraction angle of 16° and 23°, are measured carefully and found to be 1000 and 1770 respectively. The percentage of crystallinity of jute fibers is estimated as 63.90%, while the fiber shows an estimated crystallinity index of (0.435).

From the figure, it can be interpreted that the sharp peak around 23^0 represents a highly crystalline structure and the broader peak at around 16^0 and 35^0 investigated a smaller crystal defect in the crystalline structure or the fiber might be amorphous, solid lacking perfect crystallinity.

The XRD diffractograms of the jute fiber also show a noisy pattern without a peak which means that the fiber has an amorphous structure. From the above observation, it can be inferred that jute fiber can exist in both crystalline and amorphous forms. However, the Jute fiber is affirmed higher crystalline in nature.

The present study shows that jute fiber is basically composed of lingo-cellulosic material such as cellulose, hemicellulose, alpha-cellulose, lignin, and some trash amount of fat and ash. Jute is a strong fiber, but it exhibits brittle fracture and has only a small extension at break. It is one of the longest natural vegetable fiber, having good moisture content. The fiber has higher cellulose content of 54.81% and lignin 12.45%.

Tensile strength is found to be 30.14cN/tex which is comparable with other plant fiber. However, the fiber elongation is exhibits lower, showing that the fiber has low extensibility.

FTIR analysis inferred that jute fiber contains functional groups such as hydroxyl groups, aldehyde, stretching aromatic ester, primary alcohol, alkene, and halogen compounds. SEM spectra depicted that the fiber surface has rough structure with no cellulosic materials and EDX analysis shows the fiber is having major elemental component of oxygen and carbon. TGA analysis observed that the jute fiber degraded the major components of the fiber at around 400^0 C.

Again, from the XRD diffractogram, it is reveals that the fiber has both crystalline and amorphous region. Abundantly available, recyclability, eco-friendly, and outstanding physical and mechanical properties make jute fiber an alternative to synthetic fibers.

Moreover, the plantation and utilization of jute fiber could be a solution for generating employment for both urban and rural people as well as increasing the national income of a country.

In addition, jute fabrics are frequently used to control soil erosion, soil stabilization, slope reinforcement, seed protection, and weed control, and as mulching fabric, sunscreen nets for sericulture plants and cocoons, etc Cloth sacks and bags. These days, jute fiber is extensively utilized in the production of numerous value-added goods for home use as well as in the industry.

Author Contributions

Ngangkham Basanti Chanu: Investigation, formal analysis, writing—original draft. Binita Baishya Kalita: Validation, methodology, writing—reviewing. Sunita Boruah:—Formal analysis, writing—review and editing. Mamoni Probha Borah: Investigation, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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