Research Article

Effects of Geographical Conditions on the Physiochemical Properties of Natural Fiber Extracted from the Root of *Prosopis juliflora*

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Abstract
Biomass-derived Natural Fiber Composites (BDNFCs) are becoming popular in versatile applications in aerospace, biomedical, energy storage automotive, etc. due to their biodegradability, environmental friendliness, and cost-effectiveness. In the current work, root fibers extracted from *Prosopis juliflora* were selected as the natural fiber. Characterization results for physical and chemical properties on the effects of soil types and moistures in 2 different states of India, i.e. Telangana, and Tamil Nadu on fiber compositions and properties. The results reveals that hemicellulose content of tamilnadu fiber (81 wt%) is less than that of the Telangana fiber (85.7 wt%). Based on analysis results of Fourier Transform Infrared Spectroscopy (FTIR) andThermo Gravimetric Analysis (TGA), Tamil Nadu fiber has the themal stability at 239 °C and maximum degradation temperature at 359.1 °C. Whereas Telangana fiber has thermal stability at 253 °C, and maximum degradation temprature at 387.5 °C. The crystallinity indexes of Tamil Nadu and Telangana fibers were calculated, based on analysis of X-Ray Diffraction (XRD), to be 69.6% and 67.4%, respectively. The crystal sizes of Tamil Nadu and Telangana fibers were 14.38 and 13.21 nm, respectively.

Keywords: Biodegradability, Eco-friendly, Natural fiber, *Prosopis juliflora* root fiber, Root fiber

1 Introduction

Sustainable development goals state the need for the development of eco-friendly alternative materials for the production of goods, and sustainable products are contributing to the green economy and safe environment [1]. Lignocellulosic natural fibers extracted from biomass have ideal features for reinforcing polymer matrices, including high specific modulus, superior damping attributes, and improved stability of caloric characteristics [2]. Lignocellulosic natural fibers are widely used in the manufacture of non-structural components for automobiles, structural frameworks, and entertainment [3]. Natural fibers' hydrophilic properties and low heat stability limit their use in composites. Different physiochemical, and caloric treatments are used to make better qualities of natural fibers and reduce their disadvantages [4]. Plant fibers' principal chemical components include cellulose, hemicelluloses, lignin, pectin, wax, and other impurities [5]. The hydroxyl groups present in replicating cellulose units, as well as interaction with hydrogen, render it hydrophilic and determine its physical qualities [6], [7]. The stiffness of natural fibers is mostly determined by the crystalline/ amorphous proportion of cellulose [8], [9]. When the

proportion of crystalline cellulose is high, plant fibers have higher strength and stiffness [10]–[12]. The inclination of the microfibrils of cellulose relative to the axis of the plant fiber has a significant impact on the kind of distortion [13], [14]. Fibers with spiral orientation indicate ductility, whereas those with parallel orientation demonstrate rigidity [15], [16]. Hemicelluloses decompose more quickly than cellulose and lignin due to their amorphous nature, branching structure, and lower molecular weight [17], [18]. Although plant fibers can be derived from a variety of sources, including leaves, roots, and flowers, fibers taken from stems or bast have distinguished mechanical qualities due to exceptional polymerization and homogeneous quality [19], [20]. This study attempts to analyze the physio-chemical, thermal, and morphological attributes of a novel cellulosic fiber obtained from the roots of *Prosopis juliflora* plant using various characterization techniques. The ultimate goal of characterizing this unique fiber is to demonstrate that it has the potential to be exploited to reinforce polymer composites instead of traditional fibers [21].

2 Materials and Methods

In the present study, the *Prosopis juliflora* plant is identified in two geographic locations and was used for the investigation. The first fiber was identified in Karaikudi town, Sivaganga district, Tamil Nadu, India, and the second fiber was identified in Yellanda Village, Wardhannapet Mandal, Warangal district, Telangana, India. The tree can be identified from its thick rough grey-green bark that is scaly and has abundant large and sharp thorns as shown in Figure 1. The roots were collected from the plant using a chainsaw and sharp axe and immersed in water for a week. During this period, bacteria worked on the roots, aiding in the breakdown of the chemical connections that held the root layers together. The inner fibrous layers of the root were removed from the outer layer by hand. The damp fibers were then allowed to dry for 48 h in the blazing sun.

2.1 *Chemical analysis*

The amount of cellulose contained in *Prosopis juliflora* fiber (PJF) was assessed using AOAC procedure (2011.25) [22]. The hemicellulose content of PJFs was evaluated using the NFT standard 12-008. PJF's lignin content was assessed using the APPITA P11s-78 technique [22]. The wax content of PJFs was evaluated using AOAC procedure (981.11). The ash content was assessed using the AOAC procedure (942.05). The moisture content was determined using the AOAC procedure (926.12) [23].

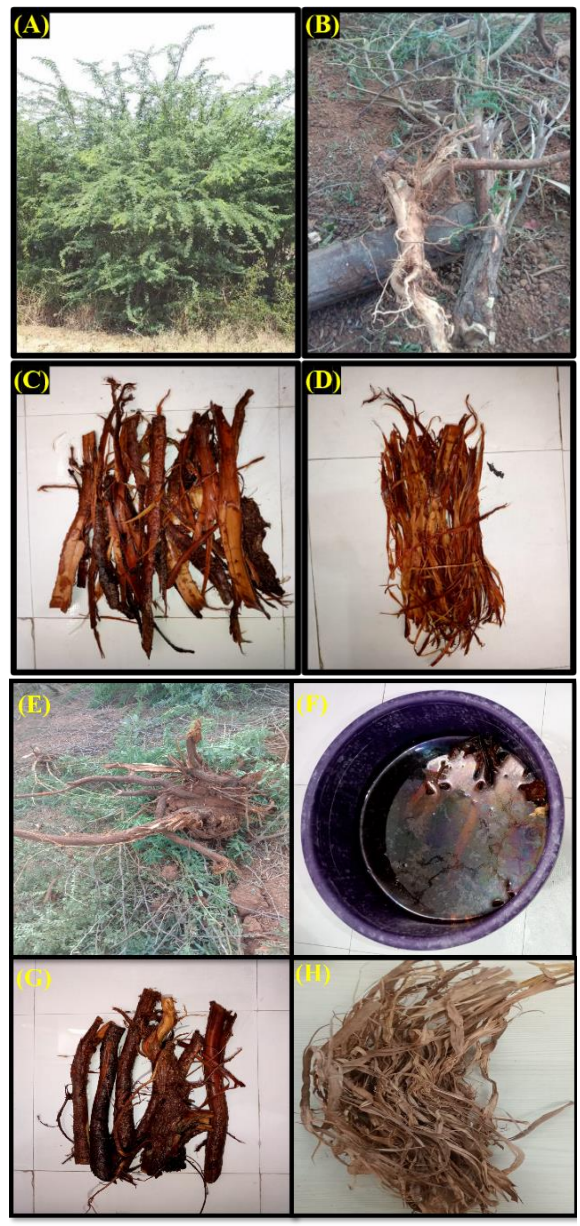

Figure 1: (A) *Prosopis juliflora* plant (TS), (B) Plant root (TS), (C) Water retting sample (TS), (D) Fiber (TS), (E) Root (TN), (F) Retting process of PHF (TN), (G) Retted root(TN), (H) Extracted PJ fibers (TN).

2.2 *Fourier Transform Infrared Spectroscopy (FTIR)*

When infrared light is combined with different types of motion, such as stretching, bending, twisting, and rocking, functional groups contained in the chemical components of natural fibers may be identified. PJF's FTIR spectra were generated using an FTIR spectrometer (Model: SHIMADZU, IRTRACER 100) with wavelengths ranging from 4000 cm^{-1} to 500 cm^{-1}. The scanning rate is 32 scans per minute with a resolution of 2 cm^{-1}. KBr Pellet was chosen as the primary operating mode.

2.3 *Thermal analysis*

Thermal stability is a crucial aspect in determining natural fibers' appropriateness for reinforcing polymer matrices. Various standard methodologies are utilized to study the thermal degradation behavior of natural fibers. Traditional techniques include Differential Scanning Calorimetry (DSC) and TGA conducted on NETZSCH STA 449F3 Thermo Gravimetric Analysis (TGA) instrument, and Derivative Thermo Gravimetric (DTG) [23]. In the present investigation, TGA and DSC were used. The change in mass and rate of change of mass with progressively increasing temperature was investigated using TG and DSC. The temperature of the PJF fiber samples was steadily raised from room temperature to 550 °C at a rate of 10K per minute. To counteract the effects of oxidation, a nitrogen environment was employed during heating.

2.4 *X-Ray Diffraction (XRD)*

The XRD pattern was studied to estimate PJF's relative proportion of crystalline cellulose and the size of its cellulose crystals. This was done using a PANalytical diffractometer benchtop model from the Netherlands. The X-ray diffraction intensity was measured throughout a 2θ range of 10° to 80° with a step size of 0.05° using a scan rate of (5°)/min. The crystallinity index (*CI*) is the quantity of crystalline cellulose found in natural fibers. The *CI* value is calculated as the ratio of the area of crystalline peaks to the overall area of the diffractogram. Equation (1) is used for estimating the crystalline index (*CI*) of PJFs [23].

$$CI = \mathrm{I_H} - \mathrm{I_M} / \mathrm{I_H} \quad (1)$$

Where I_H is the highest intensity of the peaks at 2θ angle and I_M is the minimum intensity peak. Scherrer's equation given in Equation (2), is used for evaluating the crystallite size (*CS*) of PJFs [24].

$$CS = K\lambda/\beta \cos\theta \quad (2)$$

Where, β is the peak's full width at half-maximum, λ = 1.54178 is the wavelength of X-rays, and K = 0.89 is Scherrer's constant.

2.5 *Atomic Force Microscopic (AFM) analysis*

In the current work, the AFM investigation was performed using the Atomic Force Microscope from the NT-MDT model. The AFM provided standard information on maximum Peak-to-Peak height (Sy), Ten Point height (Sz), Average Surface Roughness (Sa), Root Mean Square (Sq), Surface Skewness (Ssk), and Kurtosis Coefficient (Ska) [24].

2.6 *Field Emission Scanning Electron Microscope (FESEM) analysis*

The FESEM Analysis was performed using the equipment in CSIR-CECRI-1017 with a thin film sample of size 10 mm × 10 mm × 5 mm at ambient room conditions to look into the surface morphology of the PJ fiber through high-resolution SEM images obtained using FESEM.

2.7 *Energy Dispersive X-Ray spectroscopy (EDX) analysis*

The EDX Analysis was performed using the equipment in CSIR-CECRI-1018 [25] to assist in identifying the various elements and chemical composition present on the surface of PJ fiber. This technique uses high energy electromagnetic spectrum at 10.0 KeV of accelerating voltage to apprise the atomic weight percentage of the elements like Na, O, C, Si, K.

2.8 *X-ray Photoelectron Spectroscopy (XPS) analysis*

The X-ray Photoelectron Spectroscope of the model from PHYSICAL ELECTRONICS was used in the present study to perform the XPS Analysis. The XPS was utilized to apprise the elements that tend to appear on the surface of PJ fiber, where a thin film sample of the fiber was used for the analysis. Etching was also done on the thin film fiber sample used in the analysis. Variable spot sizes were used to record the spectra from at least three different locations on the sample.

Table 1: Comparison of chemical properties of raw PJFs and other natural fibers.

Natural Fiber	Chemical Compositions (wt%)						Reference
	Cellulose	Hemicellulose	Lignin	Wax	Moisture	Ash	
P. juliflora (Tamil Nadu)	81	9.7	2.2	0.06	6.6	0.2	This work
P. juliflora (Telangana)	85.7	10.6	2.7	0.08	0.1	0.08	This work
Cissus quadrangularis	77.17	11.02	10.45	0.14	-	-	[25]
Ficus religiosa	55.58	13.86	10.13	0.72	9.33	4.86	[26]
Acalypha indica L.	67.86	-	18.75	0.86	-	2.13	[27]
Ficus benjamina L.	64.48	11.56	9.33	0.69	8.31	5.63	[28]
Fragrant screw pine prop	73.1	12.58	7.11	0.35	-	-	[29]
Artocarpus heterophyllus	65.35	19.59	19.37	0.27	10.05	0.66	[30]
Butea monosperma	63.49	18.16	17.58	0.26	8.85	3.79	[31]
Careya arborea	71.17	27.86	14.95	0.18	9.87	0.78	[32]

3 Results and Discussion

3.1 *Chemical characterization of PJ fiber*

The chemical composition of PJ fiber and other natural fibers are shown in Table 1. PJ Fiber has higher cellulose content of 81 wt% (Tamil Nadu) and 85.7% (Telangana) while comparing with different natural fibers, such as *Ficus religiosa* (55.58 wt%) [26], *Butea monosperma* (63.49 wt%) [31], *Ficus benjamina L.* (64.48 wt%) [28], *Artocarpus heterophyllus* (65.35 wt%) [30], *Acalypha Indica L.* (67.86 wt%) [27], *Careya Arborea* (71.17 wt%) [32], *Fragrant screw pine prop* (73.1 wt%) [29], *Cissus quadrangularis* (77.17 wt%) [25]. The presence of high cellulose content in the fiber indicates high strengt h and stability of fiber and is considered an important favorable property for reinforcing with polymers. The hemicellulose content is less in the PJ fiber 9.7 wt% (Tamil Nadu) and 10.6 wt% (Telangana) while comparing with different natural fibers, such as *Cissus quadrangularis* (11.02 wt%) [25], *Ficus benjamina L.* (11.56 wt%) [28], *Fragrant screw pine prop* (12.58 wt%) [29], *Ficus religiosa* (13.86 wt%) [26], *Butea monosperma* (18.16 wt%) [31], *Artocarpus heterophyllus* (19.59 wt%) [30], *Careya arborea* (27.86 wt%) [32].

The presence of less hemicellulose content in the fiber indicates lesser microbial attack, moisture absorption, and thermal stability in PJ fiber. The lignin content is less in the PJ fiber 2.2 wt% (Tamil Nadu) and 2.7 wt% (Telangana) while comparing with different natural fibers, such as *Fragrant screw pine prop* (7.11 wt%) [29], *Ficus benjamina L.* (9.33 wt%) [28], *Ficus religiosa* (10.13 wt%) [26], *Cissus quadrangularis* (10.45 wt%) [25], *Careya arborea* (14.95 wt%) [32], *Butea monosperma* (17.58 wt%) [31], *Acalypha indica L.* (18.75 wt%) [27], *Artocarpus heterophyllus* (19.37 wt%) [30]. Low rigidity and stiffness are the structural properties shown by the fiber due to the presence of less lignin in the PJ fiber. The wax content is less in PJ fiber 0.06 wt% (Tamil Nadu) and 0.08 wt% (Telangana) while comparing with different natural fibers, such as *Cissus quadrangularis* (0.14 wt%) [25], *Careya arborea* (0.18 wt%) [32], *Butea monosperma* (0.26wt%) [31], *Artocarpus heterophyllus* (0.27 wt%) [30], *Fragrant screw pine prop* (0.35 wt%) [29], *Ficus benjamina L.* (0.69 wt%) [28], *Ficus religiosa* (0.72 wt%) [26], *Acalypha indica L.* (0.86 wt%) [27]. Natural fibers have improved properties when the wax content is low and when used for reinforcements, the interfacial adhesion is good between the fiber and the matrix.

The moisture content is less in PJ fiber 6.6 wt% (Tamil Nadu) and 0.1 wt% (Telangana) while comparing with different natural fibers, such as *Ficus benjamina L.* (8.31 wt%) [28], *Butea monosperma* (8.85 wt%) [31], *Ficus religiosa* (9.33 wt%) [26], *Careya arborea* (9.87 wt%) [32], *Artocarpus heterophyllus* (10.05 wt%) [30]. There is a major difference between the moisture content present in the two PJ fibers due to reduced soil microbial activity as a result of nutrient diffusion and low water availability. When utilized in reinforcing polymer composites, the PJ fiber's low moisture content improves the bonding strength between fiber and matrix. The ash content is less in PJ fiber 0.2 wt% (Tamil Nadu) and 0.08 wt% (Telangana) when compared to other natural fibers, such as *Artocarpus heterophyllus* (0.66 wt%) [30], *Careya arborea* (0.78 wt%) [32], *Acalypha indica L.* (2.13 wt%) [27], *Butea monosperma* (3.79 wt%) [31], *Ficus religiosa* (4.86 wt%) [26], *Ficus benjamina L.* (5.63 wt%) [28]. The presence of less ash has various impacts on the PJ fiber like high tensile strength and softness.

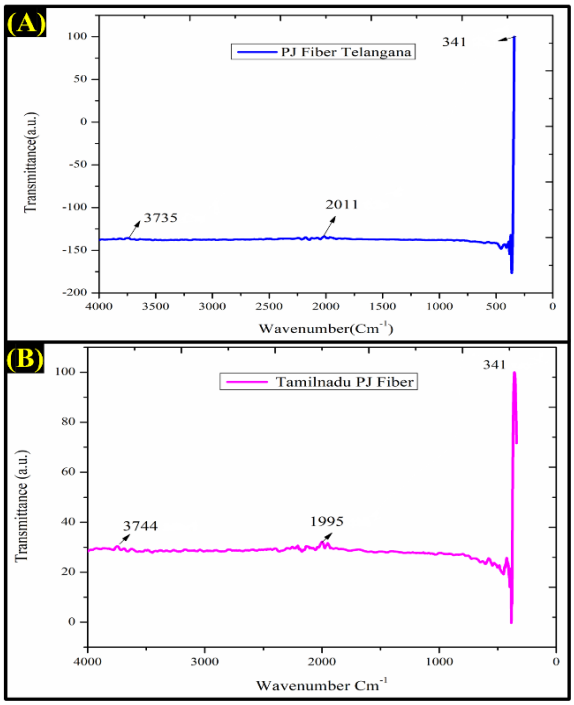

Figure 2: FTIR spectrum of PJ fiber (A) Tamil Nadu, (B) Telangana.

3.2 *FTIR analysis of PJ fiber*

The FTIR spectrum of PJ fiber is shown in Figure 2. The FTIR spectrum is used to appraise the identified chemical groups present in the PJ fiber. The bands at 3744 cm^{-1} (PJF Tamil Nadu) and 3735 cm^{-1} (PJF Telangana) represent the stretching hydroxyl groups (N-H/C-H/O-H) present in hemicellulose, cellulose, monosaccharide, and polysaccharide molecules, which further indicates the presence of amine and amide groups. The bands at 3744 cm^{-1} (PJF Tamil Nadu) and 3735 cm^{-1} (PJF Telangana) specifically represent the O-H stretching group and alcohol compound. The band at 1995 cm^{-1} (PJF Tamil Nadu) indicates the presence of a C-H bending group and aromatic compound with cellulose content and weak appearance and the peak at 2011 cm^{-1} (PJF Telangana) indicates the presence of an N=C=S stretching group and isothiocyanate compound with medium appearance. The peaks are at 341 cm^{-1} for both the PJ fiber samples.

Table 1: Thermal properties of raw PJFs and other natural fibers.

Natural fiber	Thermal properties (°C)		Reference
	Thermal Stability	Max. Degradation Temp.	
P. juliflora (Tamil Nadu)	239	359.1	This work
P. juliflora (Telangana)	263	387.5	This work
Cissus quadrangularis	230	328.9	[25]
Ficus religiosa	325	400	[26]
Acalypha indica L.	225	363.5	[27]
Ficus benjamina L.	330	470	[28]
Fragrant screw pine prop	235	331.7	[29]
Artocarpus heterophyllus	230	320	[30]
Butea monosperma	296.14	365.78	[31]
Careya arborea	248	385	[32]

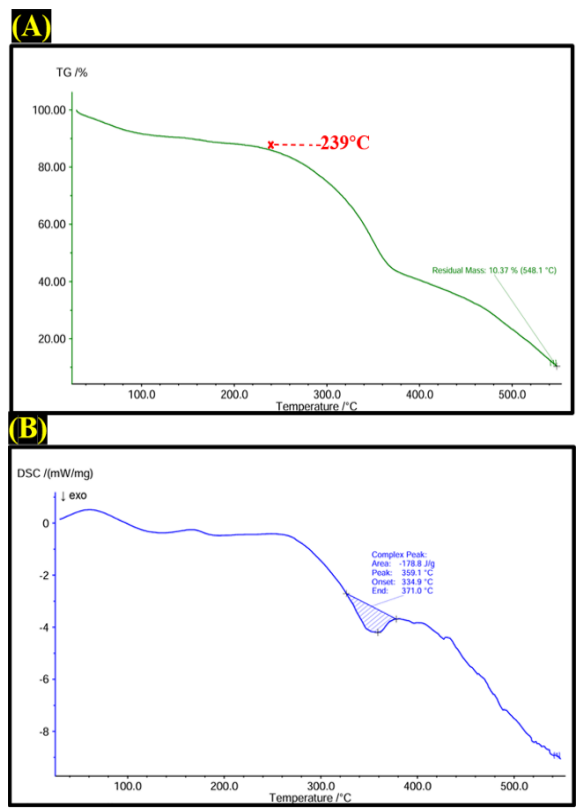

Figure 3: (A) TG curve, (B) DSC curve of PJ fiber, Tamil Nadu.

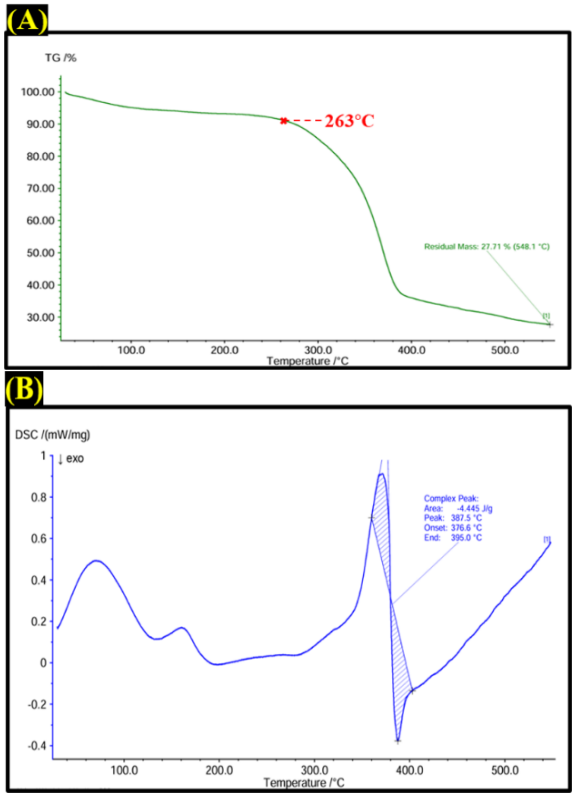

Figure 4: (A) TG curve, (B) DSC curve of PJ fiber, Telangana.

3.3 *Thermal analysis of PJ fiber*

The thermal stability of PJ fiber was examined through TGA, while the thermal degradation behavior was examined through DSC and the compared values are shown in Table 2. Figures 3 and 4 illustrate the TG and DSC curves for PJ fibers. The DSC curves show that thermal degradation of PJ fiber proceeded in three stages: primary (0–200 °C), intermediate (201–400 °C), and secondary (401–550 °C). In the primary stage, the decomposition of moisture (40–60 °C), lignin (160 °C) and wax (150–170°C) has taken place. In the intermediate stage, the decomposition of hemicellulose (220 °C) and cellulose (315 °C) has taken place. In the secondary stage, the decomposition of the ash (540 °C) takes place. The maximum degradation temperature of PJ fiber 359.1 °C (Tamil Nadu) is less than the maximum degradation temperatures of *Acalypha indica L.* (363.5 °C) [27], *Butea monosperma* (365.78 °C) [31] and *Prosopis juliflora* (Telangana) 387.5°C. Figures 3(A) and 4(A) corroborated the maximum degradation temperature of PJ fiber 387.5 °C (Telangana) is more than the maximum degradation temperatures of *Fragrant screw pine prop* (331.7 °C) [31], *Cissus quadrangularis* (328.9 °C) [25], *Careya arborea* (385 °C) [32]. The thermal stability of PJ fiber 263°C (Telangana) is greater than the thermal stabilities of other natural fibers, such as *Acalypha indica L.* (225 °C) [27], *Cissus quadrangularis* (230 °C) [25], *Artocarpus heterophyllus* (230 °C) [30] and *Fragrant screw pine prop* (235 °C) [29]. The thermal stability of PJ fiber 239 °C (Tamil Nadu) is lesser than the thermal stabilities of other natural fibers, such as *Careya arborea* (248 °C) [32], *Butea monosperma* (296.14 °C) [31], *Ficus religiosa* (325 °C) [26], *Ficus benjamina L.* (330 °C) [28] and *Prosopis juliflora* (Telangana) 263 °C. The thermal stability and maximum degradation temperature of PJ Fiber are a favorable property to be used in reinforcing low-temperature polymer composite materials due to its ability to resist the influence of high temperature.

3.4 *XRD analysis of PJ fiber*

The investigation of nondestructive crystallography revealed the distinction between the PJ fiber's crystalline and amorphous forms. The XRD peaks represent a diffraction curve with tiny, medium, and sharp peaks, indicating the position and organization of cellulose in the PJ fiber. Table 3 displays the CI and CS values for raw PJFs and different natural fibers. Figure 5 illustrates the diffraction curve of PJFs. Strong peaks at 2θ diffraction angles of 15.95°, 24.22°, 37.92° for PJ fiber (Tamil Nadu) and 16.17°, 22.26°, 24.66° for PJ fiber (Telangana) indicate cellulose IV and amorphous cellulose fractions in the fiber. The evaluated CI of PJ fiber 69.6% (Tamil Nadu) and 67.4% (Telangana) is more extensive than CI of other different natural fibers, such as *Ficus religiosa* (42.92%) [26], *Acalypha indica L.* (46.62%) [27], *Ficus benjamina L.* (55.17%) [28], *Cissus quadrangularis* (56.6%) [25] and lesser than *Fragrant screw pine prop* (74.23%) [29], *Butea monosperma* (79.99%) [31], *Careya arborea* (85.5%) [32]. The crystallite size (CS) of PJ fiber was 14.38 nm (Tamil Nadu) and 13.21 (Telangana) and are more extensive than the CS of other natural fibers, such as *Acalypha indica L.* (3.68 nm) [27], *Ficus religiosa* (5.18 nm) [26], *Ficus benjamina L.* (5.83 nm) [28], *Cissus quadrangularis* (7.04 nm) [25], *Butea monosperma* (7.4 nm) [31], *Careya arborea* (7.4 nm) [32] and lesser than fragrant screw pine prop (21.32 nm) [29].

Table 2: Crystallinity index (CI) and crystallite size (CS) of raw PJF and other natural fibers.

Natural Fiber	Crystalline Properties		Reference
	CI (%)	CS (nm)	
P. juliflora (Tamil Nadu)	69.6	14.38	Present Work
P. juliflora Telangana)	67.4	13.21	Present Work
Cissus quadrangularis	56.6	7.04	[25]
Ficus religiosa	42.92	5.18	[26]
Acalypha indica L.	46.62	3.68	[27]
Ficus benjamina L.	55.17	5.83	[28]
Fragrant screw pine prop	74.23	21.32	[29]
Artocarpus eterophyllus	-	-	[30]
Butea monosperma	79.99	7.4	[31]
Careya arborea	85.5	7.4	[32]

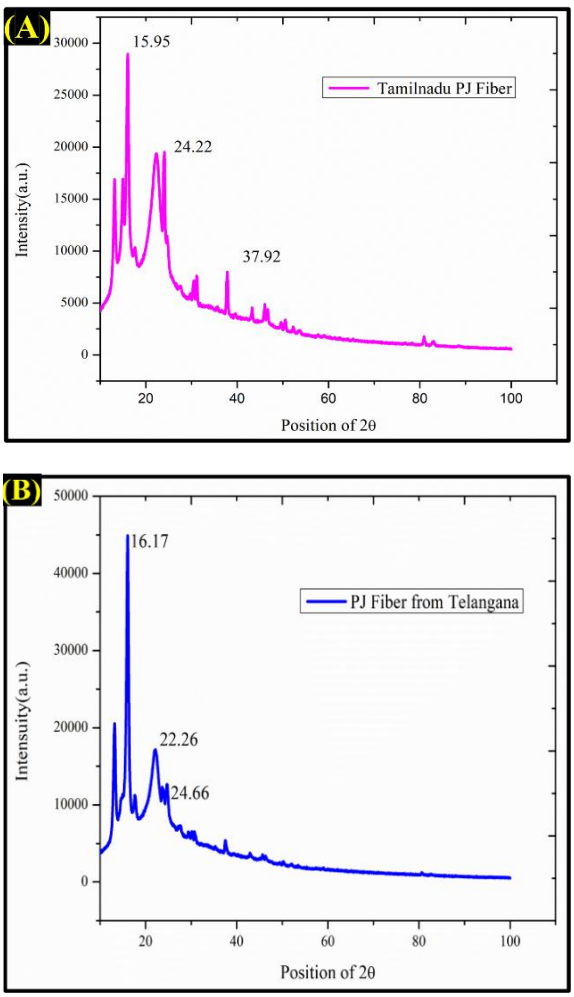

Figure 5: Diffraction curve of PJ fiber (A) TamilNadu and (B) Telangana.

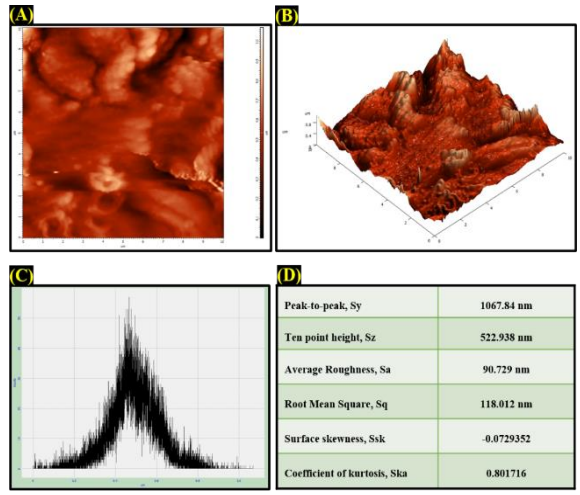

Figure 6: (A) 2D Image of PJF (Tamil Nadu), (B) 3D image of PJF (Tamil Nadu), (C) Histogram of PJF (Tamil Nadu), (D) AFM data of PJF (Tamil Nadu).

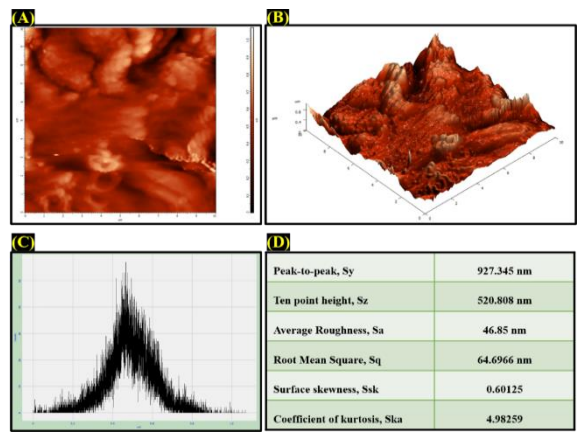

Figure 7: (A) 2D Image of PJF (Telangana), (B) 3D Image of PJF (Telangana), (C) Histogram of PJF (Telangana), (D) AFM Data of PJF (Telangana).

3.5 *AFM analysis of PJ fiber*

The 2D, 3D, and histogram of PJ fibers are shown in Figures 6 and 7. The average roughness (Sa) of PJ fiber is 90.729 nm (Tamil Nadu), which is greater than the average roughness (Sa) of PJ fiber of 46.85 nm (Telangana). The PJ fiber (Tamil Nadu) has a high roughness score, which suggests good topology and little debris on the top surface layer. Important characteristics are used to determine the fiber surface's nonlinearity and porosity such as surface skewness (Ssk), which is of value –0.0729352 for PJF (Tamil Nadu), and that is lesser than the value 0.60125 for PJF

(Telangana). Coefficient of kurtosis (Ska), which is of value 0.801716 for PJF (TamilNadu) is lesser than the value 4.98259 for PJF (Telangana). Root Mean Square (Sq), which is of value 118.012 nm, is greater than the value 64.6966 nm for PJF (Telangana).

3.6 *FESEM analysis of PJ fiber*

A Field Emission Scanning Electron Microscope was used to study the surface morphology of the PJ Fiber at magnifications of 2, 10, 20, and 200 µm. Figures 8 and 9 demonstrate the morphology of PJ fiber surfaces acquired with FESEM at different magnifications. These images depict the existence of porous gaps of dendritic structure arrangement on the surface walls of the PJ fiber. PJ fiber's FESEM micrographs revealed rough surfaces with tiny fissures and serrations. Small circular and square dendritic pores on the fiber's surface looked to be rigid, enhancing resin storage throughout the polymer matrix production process. The dispersed nature of resin on the outermost surface and surface roughness caused by the presence of pores increase the interfacial strength of the fiber layers. The presence of porous channels and a rough surface promotes better bonding with the polymer matrix. These findings provide insight into the surface's fiber arrangement and structure.

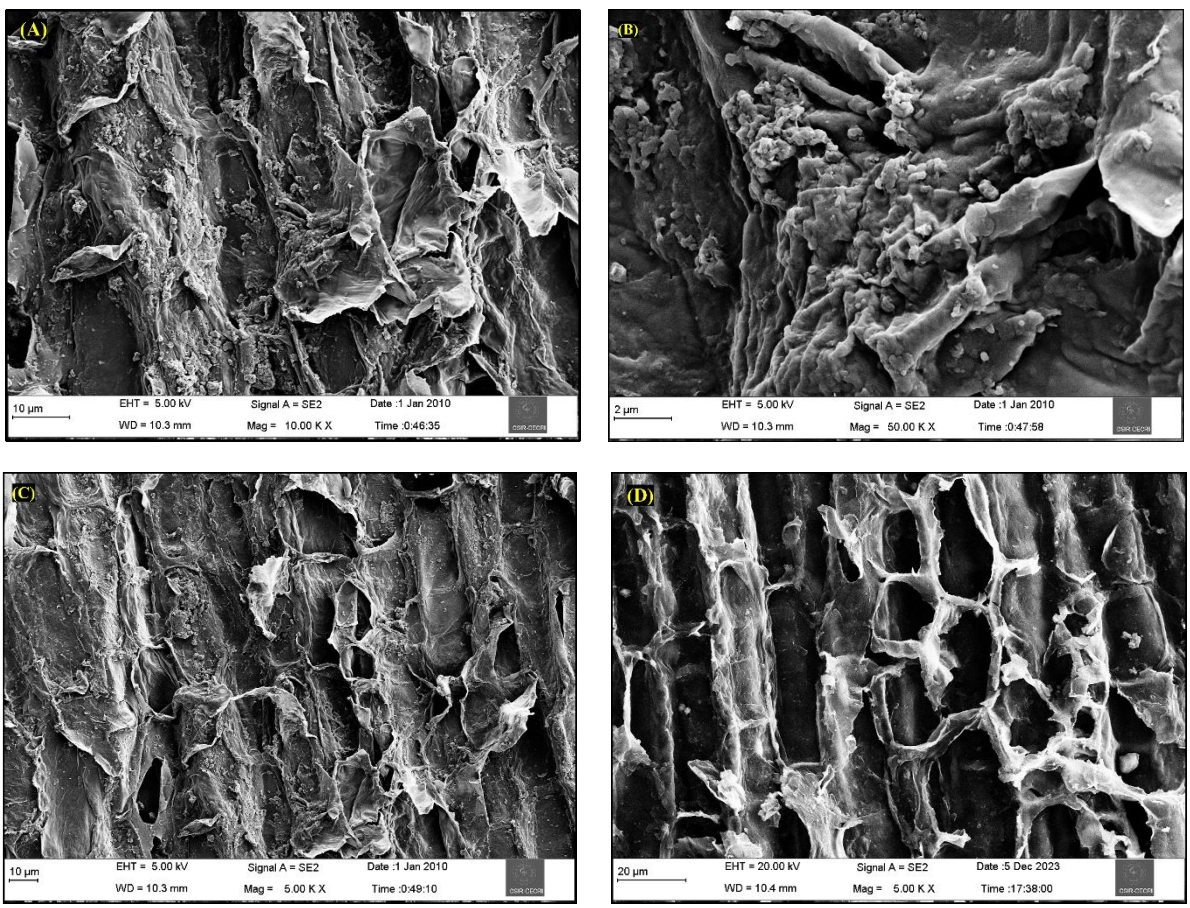

Figure 8: (A) Microwalls rupture on the surface, (B) Small debris on the surface, (C) Surface with ruptured pores, (D) FESEM micrograph of the surface wall structure of PJ fiber (Tamil Nadu).

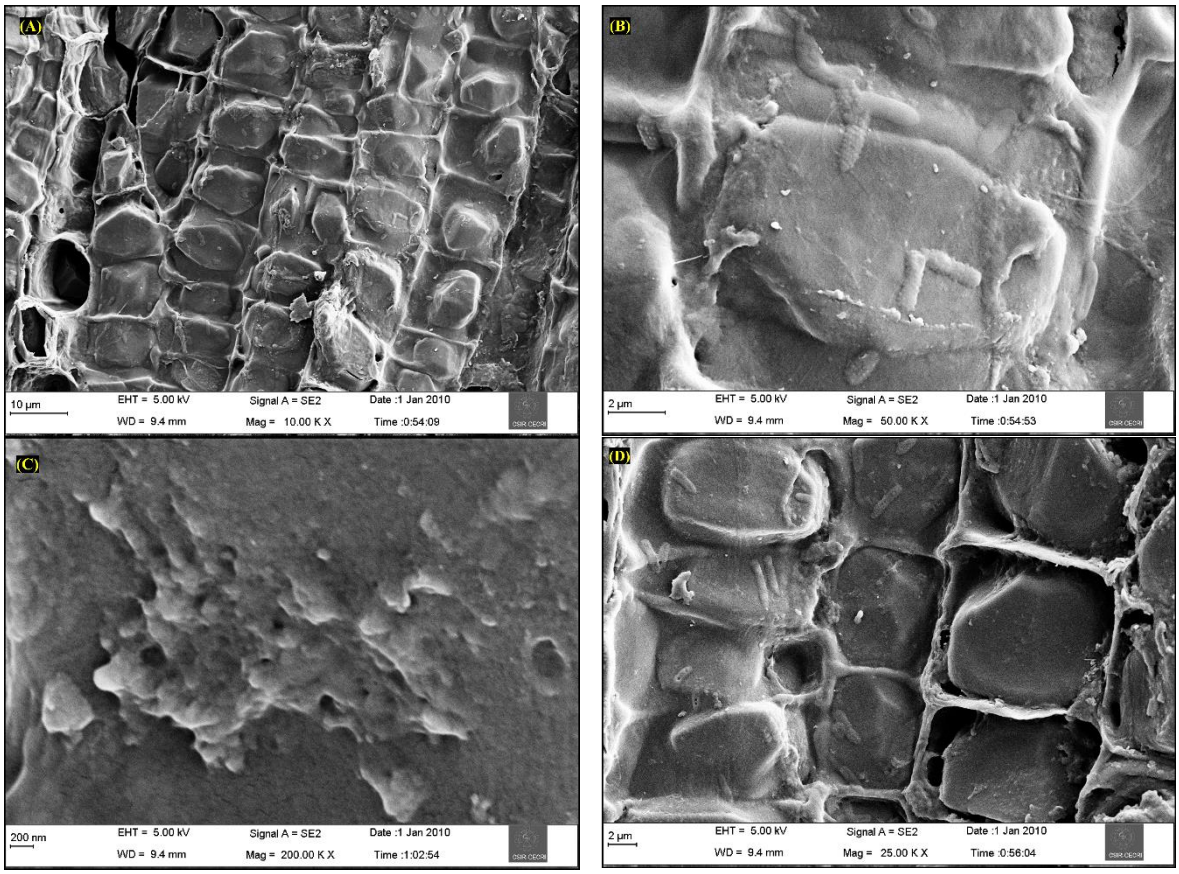

Figure 9: (a) Surface with hallow blocks and pores (b) Surface morphology cross-section of single element, (c) Surface debris (d) FESEM micrograph surface morphology of PJ fiber (Telangana).

3.7 *EDAX analysis of PJ fiber*

Figure 10 depicts the numerous components present on the surface of the PJ fiber as shown by the EDAX spectrum. The spectrum reveals the significant intensity peaks of chloride, calcium, and carbon. The chlorine, calcium, and carbon peaks were detected at 0.2, 0.25, and 0.28 keV for the PJ fiber (Tamil Nadu), respectively. The PJ fiber (Telangana) exhibited calcium and carbon peaks at 0.25 and 0.23 keV, respectively. The presence of hemicellulose and lignin in the fiber is corroborated by the significantly high carbon content (61.25%) when compared to oxygen (38.13%) in PJ fiber (Tamil Nadu) and carbon content (48.32%) when compared to oxygen (43.62%) in PJ fiber (Telangana). The presence of calcium and sodium in PJ Fiber (Tamil Nadu), as well as calcium in PJ Fiber (Telangana), with discernible peaks, suggests the existence of amorphous fiber elements such as wax and contaminants.

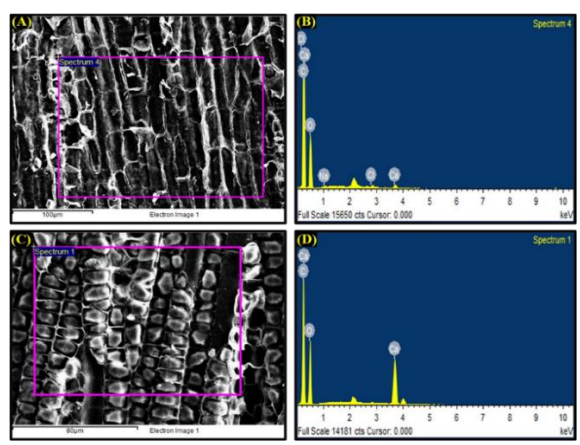

Figure 10: (A) FESEM Image of PJF (Tamil Nadu), (B) EDAX Spectrum of PJF (Tamil Nadu), (C) FESEM Image of PJF (Telangana), (D) EDAX Spectrum of PJF (Telangana).

3.8 *XPS analysis of PJ fiber*

The relative composition of the surface of the PJ fiber is shown in Figures 11 and 12. The relative surface composition of PJ fiber (Tamil Nadu) is carbon (73.3%), nitrogen (4.98%), and oxygen (21.72%). The relative surface composition of PJ fiber (Telangana) is carbon (69.77%), nitrogen (1.87%), and oxygen (28.37%). The O/C ratio of PJ fiber (Tamil Nadu) 0.3 is lesser than the O/C ratio of PJ fiber (Telangana) 0.4. Higher C/O ratio results in fiber surface having better hydrophilicity, which is of significance for reinforcing cellulosic fiber composites. The C/O ratio of PJ fiber (Tamil Nadu) 3.37 is greater than the C/O ratio of PJ fiber (Telangana) 2.46. PJ fiber has the potential to be used in reinforcing composites.

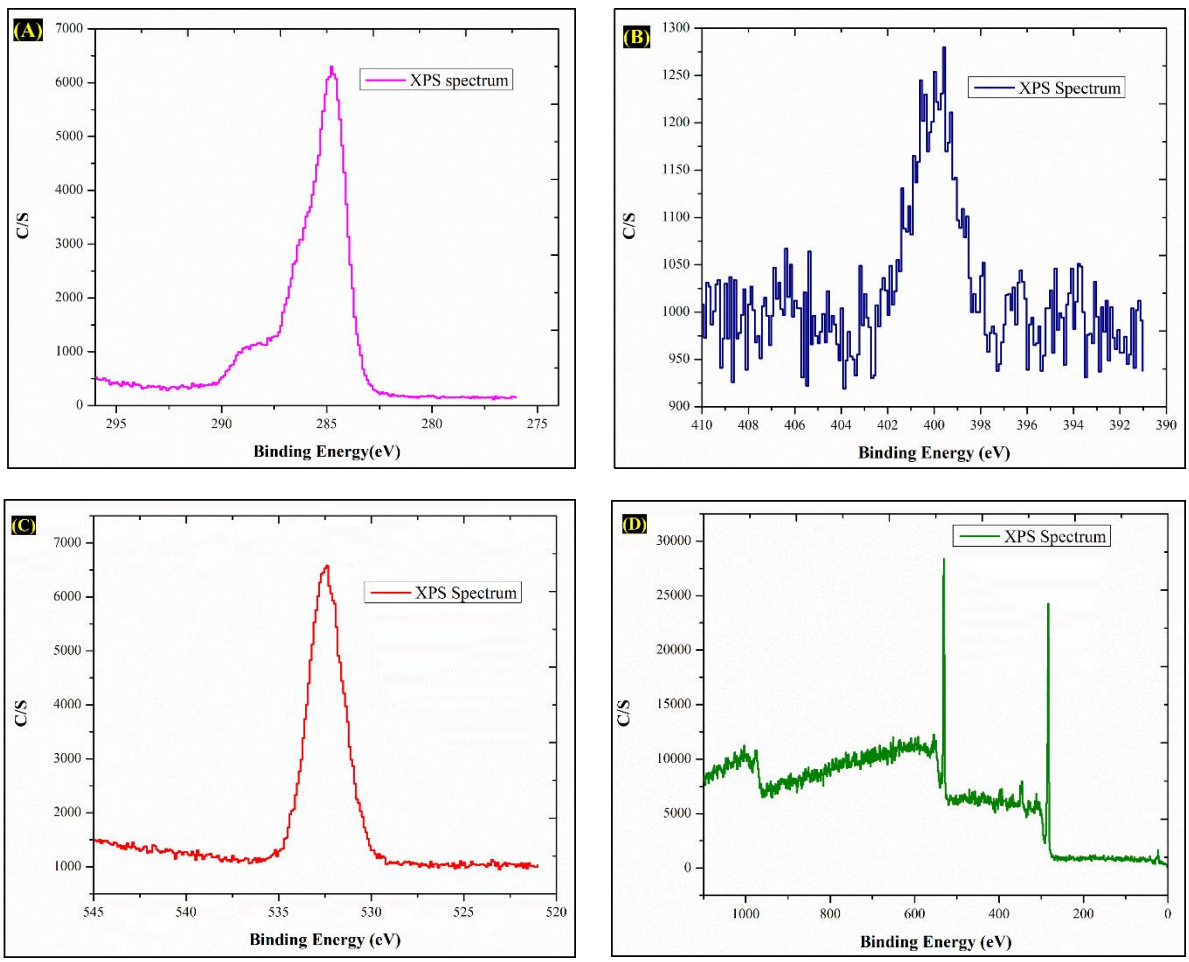

Figure 11: (a) XPS analysis of PJ fiber (b), (c)The peak binding energy of TN PJ fiber (d) Relative surface composition of PJ fiber (Tamil Nadu).

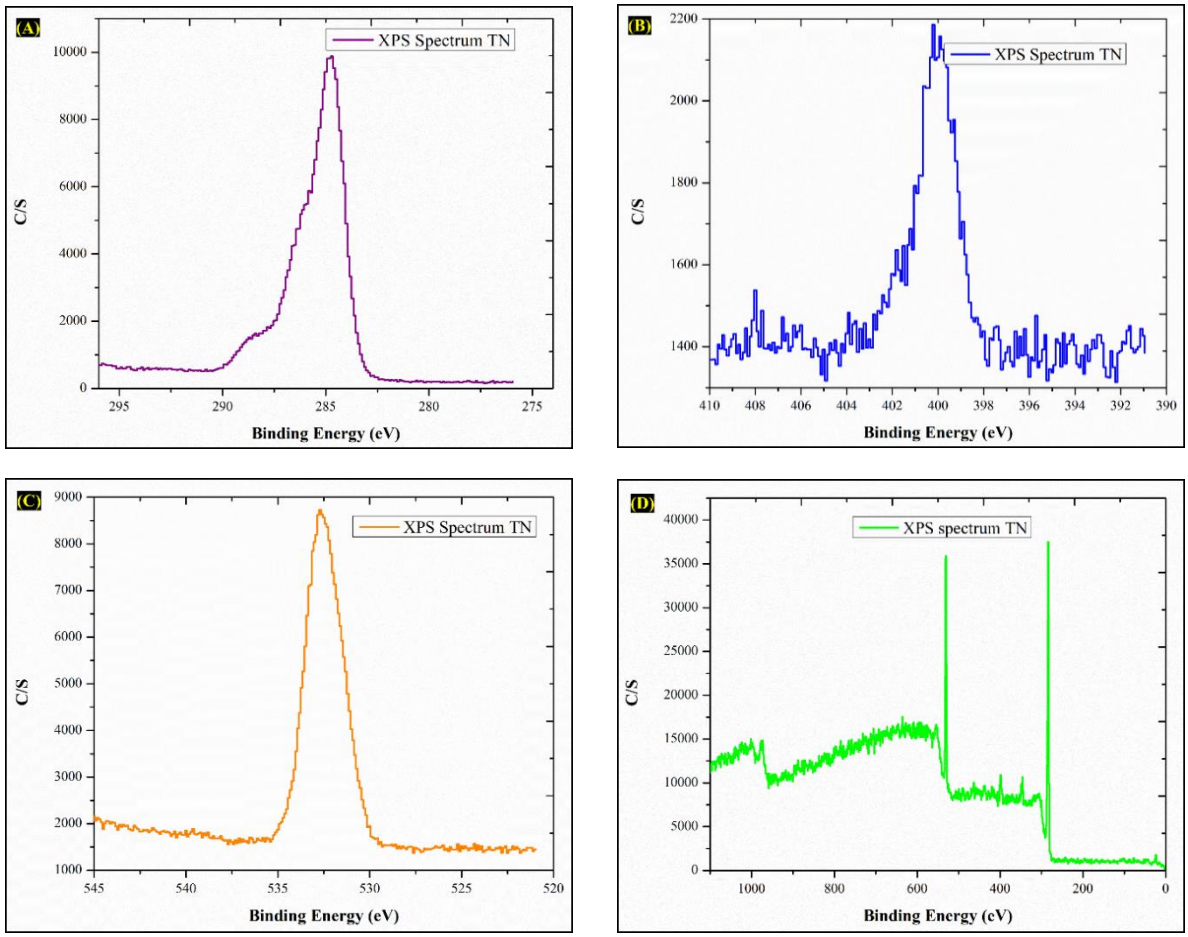

Figure 12: (a) XPS analysis of PJ Fiber (b), (c) The peak binding energy of TS PJ fiber (d) Relative surface composition of PJF (Telangana).

4 Conclusions

Several characterization experiments were performed in this work to investigate the chemical, physical, and thermal properties of cellulosic fiber extracted from *Prosopis juliflora* roots. According to the test results, the fiber has a significant quantity of cellulose (85.7%) and less amorphous components, such as hemicellulose (9.7%), lignin (2.2%), and wax (0.06%). Because of the low proportion of hemicellulose, the fiber is hydrophilic. A small amount of wax (0.06%) and ash (0.08%) increased the adhesion of interfacial surfaces between the reinforcement layer and the continuous phase matrix. Because of its capacity to withstand the effects of high temperatures, PJ fiber's thermal stability (263 °C) and maximum breakdown temperature (387.7 °C) make it an ideal material for reinforcing low-temperature polymer composites. The increased crystallinity index (69.6%) leads to the higher tensile strength. The high roughness (90.729 nm) suggests that the PJ fiber's top surface layer has good topology and little debris. The distribution of resin on the surface area, as well as the surface roughness generated by the presence of pores, improves the fiber layers' interfacial strength. A greater C/O ratio (3.37) makes the *Prosopis juliflora* fiber surface more hydrophilic, which is useful for reinforcing cellulosic fiber composites. As a consequence, it can be concluded that *Prosopis juliflora* fiber is the best reinforcing material for polymeric matrix composites.

Author Contributions

J.R.H., K.A.P., T.F.S., C.M.S.S.: conceptualization, investigation, reviewing and editing; K.P., J.R.H.: investigation, methodology, writing an original draft; S.S., S.B.: research design, data analysis; All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

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