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Thermal, chemical, tensile and morphological characterization studies of bamboo fibre extracted from the indian species *bambusa bambos*

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Abstract

The objective of this research is to investigate the extraction and characterization of a particular kind of Indian bamboo family plant known as *Bambusa bambos*. The fibres were extracted from the bamboo plant in the form of strips using the retting process and separated as thin fibres after the stamping process. The extracted raw bamboo fibres were chemically modified in a 5% alkali solution. The thermogravimetric analysis (TGA), x-ray diffraction (XRD), and scanning electron microscopy (SEM) were used to investigate the thermal, crystalinity, and morphological properties of untreated and alkali (NaOH) treated bamboo fibres. The ASTM standard was followed for the chemical composition and tensile testing of raw and chemically treated bamboo fibres. In contrast to raw bamboo fibres, alkali-treated bamboo fibres had a 5% drop in hemicellulose concentration. In the alkali-treated state, weakly bonded containments were removed from the fiber's surface, exposing the cellulose over a wider surface area. As a result, the thermal stability of the alkali-treated fibres was enhanced as compared to raw bamboo fibres. The increased amount of cellulose content and decreasing aspect ratio of the alkali-treated bamboo fibers lead to increased tensile strength. A significant improvement in the crystallinity index (broad band width of the second peak) was observed in the alkali-treated condition, which may occur due to the removal of hemicelluloses. Based on their performance, the chemically treated bamboo fibres can be used as effective reinforcement elements for the development of polymer matrix composites in the automobile and construction industries.

1. Introduction

Natural plant fibre extraction has attracted many attentions lately, due to the reduction in non-renewable fibres and increased environmental protection awareness. Natural fibres are biodegradable, because of their natural source. As a result, they are more promising than synthetic fibres [1]. Composite materials are stronger, stiffer and less dense than steels. They also offer excellent resistance to fatigue. Composites are ideal alternative materials in aerospace and automotive for structural applications, considering the afore mentioned qualities [2]. More importantly, an environmental concern has drastically reduced due to the usage of synthetic fibres. Therefore, several studies have been reported on possibility of replacing synthetic fibres with natural fibres for

the production of fibre-reinforced polymer (FRP) composites [3]. Fibres are used for different purposes in materials science and engineering, including their most popular application as reinforcement in various composites. Today, natural fibre is one of the easily available renewable biodegradable materials with superior characteristics, when compared with synthetic counterparts. Bamboo fibre, an example of natural fibre, has attracted more attention than other natural fibres, due to its short natural development phase, accessible resources and significant flexural response, among others. The natural structure of bamboo fibre is complicated, but it possesses outstanding mechanical qualities. Among other products manufacturing industries, building/construction, automotive and aerospace industries are the leading users of bamboo fibres. However, they are susceptible to moisture absorption, restricting their specific usage in engineering. Therefore, it is necessary to gain a better understanding of bamboo fibre to improve its applications.

Research on bamboo fibre has become necessary in recent years. Bamboo fibre has various advantages over other natural fibres, including low density, good stiffness and biodegradability [4]. It is environmentally friendly, as bamboo grows at a fast rate and absorbs a lot of atmospheric carbon dioxide [5]. Fibres from bamboo plants are used for a number of technical applications. Bamboo fibres are very good at absorbing moisture and allowing air to pass through, because their fibrils are spread around the circumference of the fibre. They are simple to classify and use [6–10]. Besides, it is difficult to recycle traditional thermoset composites at the end of their useful lives. For example, landfills remain the most cost-effective alternative method of disposing turbine blades after their technical and economic lives. However, as waste management directives become more stringent, this method will be limited in the near future. Natural fibres have sparked interest, due to their excellent performance with regard to particular mechanical characteristics, ease of presence, environmentally friendly nature, recyclability, non-toxicity when inhaled, non-abrasion to machinery, straight extraction from their source without further processing, lower power consumption and limited cost, among others [11–13]. Natural fibres can be used to create composite materials by combining them with thermosetting or thermoplastic polymers, competing or replacing conventional E-glass composites, wood-reinforced composites and aluminum alloys.

Despite the fact that bamboo fibres have been widely explored in the field of fibre reinforced composite materials, there are still some gaps to study diverse bamboo species in different regions. As a result, the fibre extraction of bamboo fibres in *bambusa bambos* needs to be researched in order to understand the reinforcing impact in the polymer matrix. Considering the aforementioned circumstances, it is important to investigate the chemical, mechanical, thermal, and morphological properties of both untreated and treated bamboo fibres from the new extraction source. This work focuses on an experimental evaluation of the above-mentioned characteristics utilizing thermogravimetric analysis (TGA), x-ray diffraction (XRD), mechanical tensile testing, and scanning electron microscopy (SEM), among other characterization techniques. Furthermore, this research has been proven to be beneficial in broadening the application spectrum of bamboo fibre, especially as a feasible reinforcing element in different FRP bio-composite constructions. Technical applications in relevant manufacturing sectors might benefit from bamboo FRP bio-composite constructions.

2. Experimental procedures

2.1. Materials and methods

2.1.1. Continuous bamboo fibre extraction

A bamboo plant grown in the area of Krishnagiri in Tamil Nadu, India, is shown in figure 1(a). A bundle of stalks was kept in the reservoir. A 20-kg dead weight was placed over the stalks to ensure complete wetting. During the retting process, the water penetrating into the central stalk portion swells the inner cells, bursting the outermost layer, thus increasing the absorption of both moisture and decay-producing bacteria. Through a continuous monitoring process, perfect judgment has to be taken to extract the fibres without losing their strength. Accordingly, after three months of retting, bamboo stalks were taken out of the wetting and subjected to drying for a period of two weeks. Firstly, the bamboo stalks were divided in the form of rectangular stripes for the entire length of the stem. In the second step, a gentle stamping process was employed manually to separate the thin fibres. Figure 1(b) shows the extracted bamboo fibres in the form of bundles for further usage. Then, bamboo fibres were placed in an oven set at 80 °C for five hours to remove moisture before characterization and testing.

2.1.2. Treatment with alkaline

The bamboo fibres were soaking in water and later they were cleaned, using deionized water at an ambient temperature. After drying the fibres for 24 h in an oven, they were kept in a desiccator. Later, the fibres were gently agitated for 1 h in a 4% of aqueous sodium hydroxide (NaOH) solution. Water was then used to rinse the fibres, accompanied by de-ionized water until the pH of the rinse water equaled that of the demineralized water.

Figure 1. (a) Bamboo Plant (b) Extracted bamboo fibre.

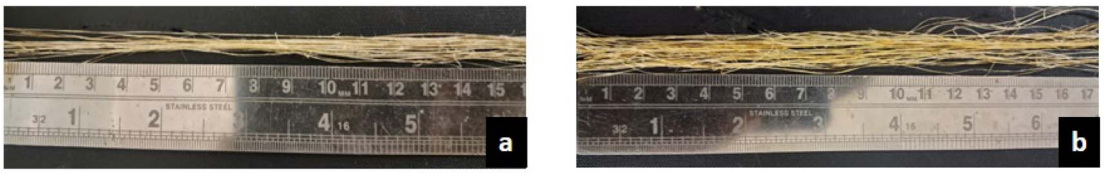

Figure 2. (a) Untreated bamboo fibre (b) Alkali treated bamboo fibres.

Prior to the testing the fibres were dried in a pre-heated oven at 65 °C for 24 h. Figures 2(a) and (b) shows the photographic view of untreated and treated bamboo fibres.

3. Results and discussion

3.1. Chemical compositions of untreated and treated bamboo fibres

The eight principal chemical components of bamboo were cellulose, hemicelluloses, lignin, pectin, wax, ash content, moisture content and density, which were intricately linked in a complicated structure. The primary goal of this chemical analysis was to determine the concentration of lignin, cellulose, hemicelluloses, wax, and moisture in raw and chemically treated bamboo fibre using typical conventional chemical analyses. As a result, the cellulose component was estimated using the methods outlined in Kurshner and Hoffer's method [14]. The crushed fibres were first extracted with dichloromethane, and then dipped in a solution containing ethanol and 95% nitric acid. The cellulose that corresponded to the insoluble fraction of the samples was weighed. The Klason technique [15] was used to determine the lignin content of the samples. Crushed materials were extracted with dichloromethane before being hydrolyzed in a 72% sulphuric acid solution. Lignin, the sole insoluble component, was extracted and measured from the fibre. The hemicellulose concentration was determined using the NFT 12–008 standard. Hydrobromic acid was used to heat the samples. The hemicellulose was converted into furfural, which was then distilled and quantified using spectrophotometry. The wax content of the bamboo fibre was determined using the Conrad technique [16]. The bamboo fibre samples were crushed and extracted using soxlets in ethanol for 6 h. Sugar, wax, and other alcohol-soluble compounds were found in the resultant solution. To extract the wax from the alcohol solution, the solution was transferred to a separator funnel and chloroform was added. Purified water was then added, resulting in the formation of two distinct layers of chloroform and alcohol. The chloroform evaporated from the solution after separation, leaving a waxy residue. Following extraction, the dried residue and bamboo fibre samples were weighed, and the wax content was

Table 1. Chemical contents of alkali treated and untreated bamboo fibres.

	Cellulose (%)	Lignin (%)	Hemi cellulose (%)	Pectin (%)	Wax (%)	Ash content (%)	Moisture content (%)
Bamboo untreated	74.2	10.2	19.5	4.5	0.97	1.6	8.4
Bamboo treated	74.8	12.3	18.5	2.6	0.47	2	7.7

Table 2. Percentage of primary chemical components present in the different family of bamboo species.

Species	Cellulose (%)	Hemi cellulose (%)	Lignin (%)	Reference
Haur hejo	52.3	19.15	20.01	
Tali	46.91	17.29	21.3	
Phyllostachys Heterocycla	37.21	21.6	24.29	[21]
O.abyssinia	52.06	16.90	22.47	
yushania alpina	51.06	20.19	23.79	

expressed in terms of the bamboo fibre samples' initial weight. Table 1 depicts the various chemical components present in the raw/untreated and treated bamboo fibres used in this work.

Cellulose is the basic building block of bamboo fibre cell walls, which primarily consists of three elements: oxygen, hydrogen and carbon [17]. Plant cell walls typically contain cellulose in the form of microfibrils [18]. Cellulose contents of treated and untreated/raw bamboo fibres were 74.8 and 74.2% respectively. The cellulose content, which is directly related to the age of the bamboo, is the most important factor that influences the tensile strength of bamboo fibre along the grain. It is important to note that the cellulose content of bamboo decreases with age [19]. Hemicellulose is a non-polymerized amorphous material found between fibres. Hemicellulose is a heteropolysaccharide made up mostly of D-xylose, L-arabinose and 4-O-methyl-D-glucuronic acid, with xylan as the major chain [20]. Distilled water was used to extract the majority of the polysaccharide components. However, alkaline extraction increased the amount of xylose. After chemical characterization of the raw and treated fibres, the hemicellulose contents within the fibres were 18.5 and 17.5%, respectively. In order to understand the effectiveness, a comparative study was undertaken between bamboo fibres extracted from the *bambusa bambo* and other family extracted bamboo fibres, and the same was shown in the table 2. From the result of analysis, it was clearly observed that the % of cellulose was found to be higher in the bamboo fibre used in this work. This quality will help to achieve the higher tensile strength and in turn the reinforcement effect of fibre in the polymer matrix as well. Similarly, the lower value of hemicellulose and lignin also helps to improve the interfacial bonding between the fibre and polymer.

3.2. Tensile test

In accordance with the ASTM D 3822–01 standard, raw and untreated bamboo fibres were tested in dry conditions under tensile stress at a fixed gauge length (GL) of 50 mm in an Zwick/Roell universal testing machine of type 5500 R. Pneumatic grips with 0.4 MPa pressure were employed to clamp the fibre. The load was measured using a load cell with a capacity of 1.0 kN. A short-stroke transducer with a resolution of around 0.1 m was used to measure the displacement of the fibre. Tensile testing was carried out at a cross head speed of 0.1 m m /m i n. Because natural fibres vary in quality, 25 samples were evaluated, and the average result was provided. All tests were carried out at room temperature (21 °C) and a relative humidity of about 65%. The tensile strength and percentage of elongation for both raw and alkali treated bamboo fibre is shown in figure 3.

The bamboo fibre was followed the ductile material behavior in the load- deflection curve in all the 25 samples. The elongations at break and fibre tensile strength were calculated using stress-strain plot. The elongation at break was 1.8 and the average tensile strength was 112 MPa for the treated fibres. Whereas, the average tensile strength of 68.16 MPa were recorded by the untreated samples. The higher tensile strength was found in the case of alkali treated condition which is 44 MPa more than that of raw bamboo fibres. The increasing amount of cellulose content in the alkali treated condition expose regularly arranged microfibrils which could bear more load than the weakly bonded chemical components. The decreasing value of % of elongation ensures the higher stiffness in the alkali treated bamboo fibre. The removal of hemicellulose and lignin was also one of the reasons for obtaining the better tensile strength. They help to keep fibrils in place and prevent particles from slipping [22, 23]. Due to the removal of the unwanted contaminants over the fibre surface, the diameter of the bamboo fibre got reduced in the case of alkali treated condition. The diameter of raw and alkali treated fibre is shown in the figure 4. The average diameter measured from the optical microscopy image was used to calculate the tensile strength from the load-deflection curve.

To understand the mechanical behavior of newly extracted bamboo fibres, the tensile properties of other extracted bamboo fibres from different sources are presented in table 3. Based on the analysis, the bamboo fibres used in this work showed less tensile strength and percentage of elongation in comparison with the other bamboo fibres extracted in different region. However, the tensile strength of this bamboo fibre is higher than that of many other natural fibres presented in the table 4.

Figure 5 illustrated the load deflection curve for 25 bamboo fibers used in the untreated and alkali treated conditions. In both the cases, a linearly increasing load was observed with varying magnitude of load. Due to the difference in the fiber morphology and internal flaws the variation in the load may be occurred. A large load

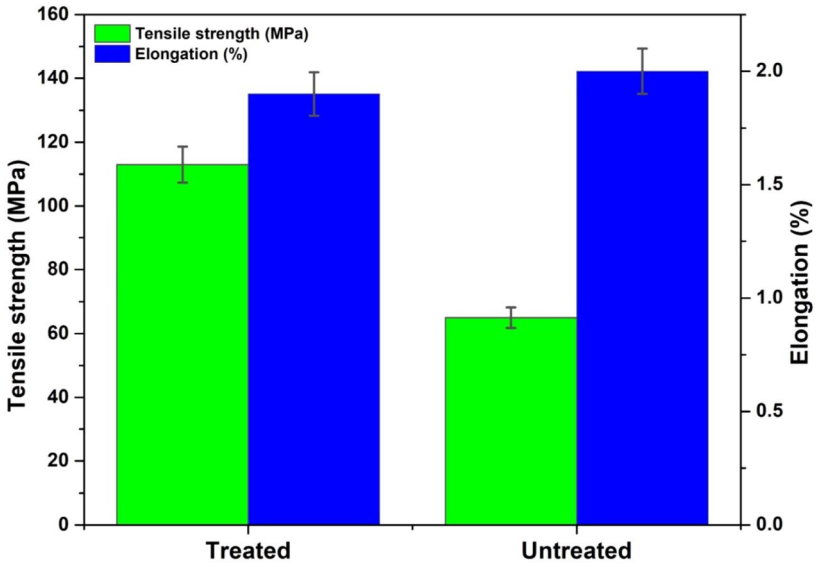

Figure 3. Tensile properties of untreated and treated bamboo fibres.

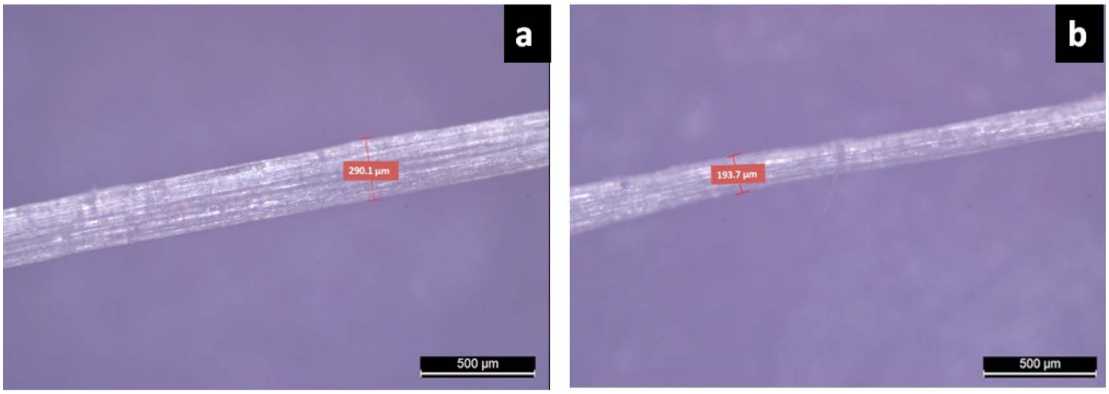

Figure 4. Optical microscopy images of diameter measurement for raw and alkali treated bamboo fibre.

Table 3. Tensile properties of different bamboo fibres extracted in various species.

Species	Tensile strength (MPa)	% of Elongation	Reference
Moso	150.1	—	
G.S.Gamble	368.3	—	
Bamboo Vulgaris	366.8	7.7	[21]
Neosinocalamus affinis	590	8.21	
Bambusa vulgaris	339	—	
Vulgaris	212	3.98	
yushania alpina	411.7	2	

variation of 70 kgf cm^{-2} to 180 kgf cm^{-2} was noticed in the case of treated condition which implies that the variation may be possible in the fiber structure during the chemical modification. After the removal of contaminants fiber diameter may be decreased in the case of chemical treatment which may cause higher load carrying capacity. However, a small variation in slope was observed from the loading pattern for all the samples. In contrast, a small load variation of 40 kgf cm^{-2} to 80 kgf/cm^2 was obtained in the case of untreated bamboo

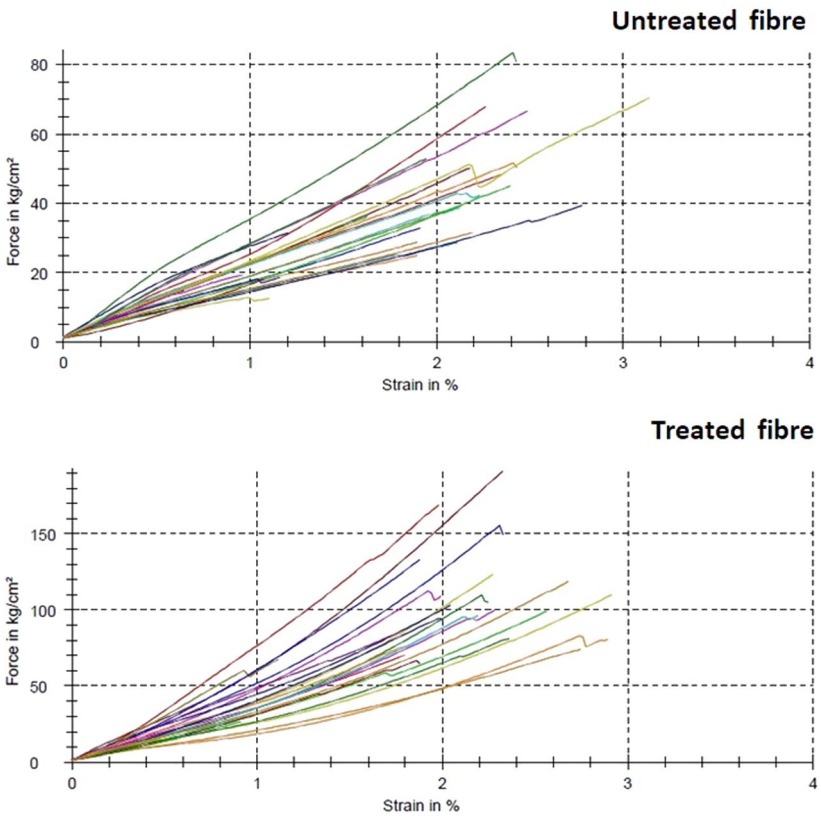

Figure 5. Load- deflection curves for untreated and treated fibres.

Table 4. Mechanical characteristics of some natural fibers.

Fiber	Tensile strength (MPa)	Density (g cm^{-3})	Tensile modulus (GPa)	Reference
Bamboo	140–1200	0.59–1.10	12–32	[24]
Rachis	74.26	0.61	2.31	
Rachilla	61.36	0.65	2.34	
Spatha	75.66	0.69	3.14	
Sisal	80–855	1.00–1.50	9–38	
Jute	187–800	1.43–1.52	3–64	
Cocount husk fiber	126–148	1.15,	3.1–4.3	
Date palm	97–196	1.20	2.5–5.4	
Kapok	45–64	1.47	1.73–2.55	

fiber due to the similar kind of fiber structure. As depicted in the tensile strength values shown in figure 3, the decreasing fiber diameter after the alkali treatment leads to the enhancement of tensile strength for the corresponding loading. In both the cases, the % of elongation for most of the samples falls between 2 to 3. The average tensile strength and modulus values were calculated based on the ultimate load and the area of cross-section of the fiber and shown in the figure 3.

3.3. Morphological study

The morphological structures of the surfaces of both bamboo fibres were obtained, using scanning electron microscope (ZEISS). At 250, 500 and 1000x magnifications, figures 6(a) and (b) depict the surface morphologies of untreated and treated bamboo fibres, respectively. Cellulose, the material that makes up the bulk of the cell wall, was the major constituent of a single fibre. According to figure 4, individual bamboo fibres' diameter reduced as the concentration of NaOH increased; a similar effect was also noted for fruit fibres [25]. As the alkali concentration increased, the diameter shrank, whereas the length grew at low alkali concentration and then shrank at high alkali concentration. The loss of weakly bonded matrix and microfibril aggregations following alkali treatment may have contributed to the fibre's diameter modification. The microfibril aggregates also got more distinct, and the surface wrinkle became more noticeable. The surface of the untreated fibres was smooth.

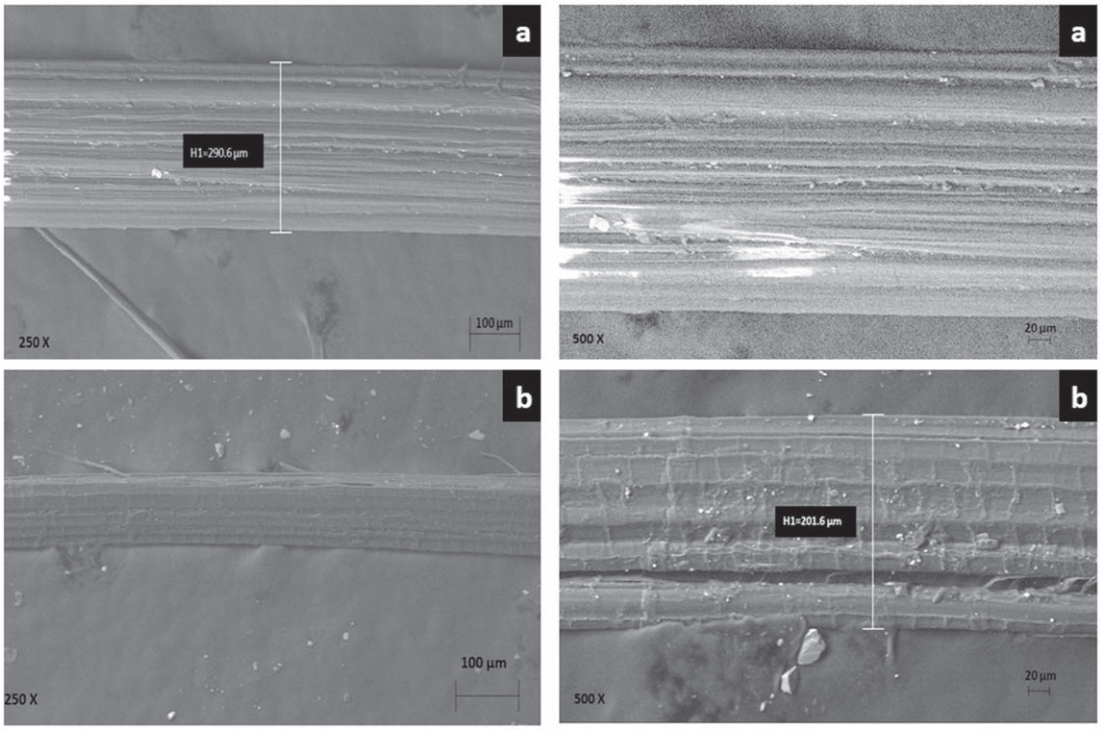

Figure 6. Micrographs of (a) untreated and (b) treated bamboo fibre surface morphologies.

As indicated in the figures, the direction of the cellulose microfibril aggregates was not immediately apparent. Additionally, the cellulose microfibril aggregates in figures a and b at high magnification can not only be seen clearly but also some pores were found between microfibril aggregates. The skeleton provided bamboo fibril, its elasticity and strength. Several filler components, including pectin, hemicellulose and lignin can be observed in comparison with microfibres and cellulose in the fibres. Non-cellulosic molecules joined the single fibres together. Consequently, the fibres became more resilient to external influences. The results obtained agreed with other studies, which confirmed that technical fibres were scattered thickly in untreated fibre and thinly inside the layer of treated fibre on cross sections. The bamboo materials had a blend of gradient materials impact with significant development in structure and performance, because the density decreased steadily in untreated fibre. It demonstrated that after alkali treatment, the matrix in the cell wall was eliminated. The isolated technique utilized in this work, according to our earlier research, can remove the lignin from bamboo fibre [26]. The cell wall's microfibril aggregates and surface shape were altered by alkali treatment. Compared to untreated bamboo fibres, bamboo fibres that have undergone an alkali treatment had increased surface wrinkling. The microfibril aggregates underwent a granular structure shift as a result of the 5% NaOH treatment, which changed them from a randomly interwoven structure.

After the removal of weakly bonded chemical constituents, a smooth surface was clearly visible in the alkali treated fibres as shown in figure 4. Further, separation of fibril also clearly visible after the removal of bonding materials. To ensure the morphological changes on the fibre surface the surface roughness test was conducted using Mitutoyo SJ-400 contact profilometer. From the result of analysis, the lowest mean average surface roughness (Ra) value of 0. 351 was found in the case of alkali treated fibre when compared to the untreated fibre (Ra= 0.899).

3.4. XRD analysis

The monochromatic Copper K-alpha radiation (K-alpha = 1.54060 A) over an accelerating voltage of 45 kV, 25 mA and a Bruker D8 Advance Eco Powder x-ray diffraction apparatus (Germany) were used to produce the bamboo fibre XRD peaks and angle of 10 to 80 degrees (2-theta). Figure 7 shows an XRD image of both untreated and treated bamboo fibres. Moving forward, three peaks were observed in the XRD images. The first peak was low intensity, the second was high intensity and the last peak was very low intensity. The peaks of the bamboo fibre that were obtained using XRD were consistent with previously reported studies. Using the Segal method [27], the crystallinity of bamboo fibre powder was determined. Sharper peaks were produced with the addition of raw bamboo fibre, affecting the crystallinity. The three crystallographic plane peaks occurred at $2\theta = 15.26°$ (little broad hump), 22.6° (sharp intensity) and 34.5° (very small broad hump), respectively, corresponding to

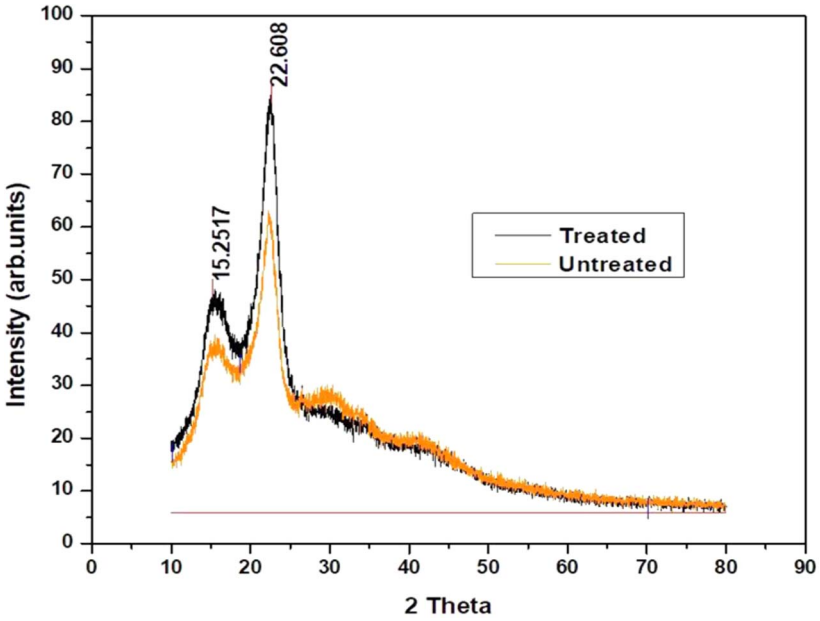

Figure 7. XRD images of raw/untreated and treated bamboo fibres.

Table 5. Crystallinity index value for the raw and alkali treated bamboo fibre.

S.no	Fibre	*CrI (%)*
1	Treated bamboo fiber	86.62
2	Untreated bamboo fiber	73.82

the (101), (002) and (040) crystallographic plane reflections [28]. Treated bamboo fibre, which exhibited a stronger peak at 22.6°, recorded the highest degree of crystallinity. This resulted from the hydroxyl group of cellulose, generating inside molecules. They were robust hydrogen bonds. Due to the features of the bamboo fibre, untreated and treated types recorded different crystallinities. The broad, less intense peak showed the short-order organization of the cellulose atom, whereas the acute, intense peak indicated the long-order arrangement. The maximum crystallinity index value was noticed as shown in table 5 for the alkali treated bamboo fibres which is normally support to improve the tensile strength of the fibre.

$$CrI = \frac{H_{22.60} - H_{15.25}}{H_{22.60}}$$

Where $H_{22.60}$ and $H_{15.25}$ represent the height of the peaks at $2\theta = 22.60$ and $2\theta = 15.25$.

3.5. TGA

Thermogravimetric analysis (TGA) serves as a principal methodology employed to ascertain thermal characteristics encompassing stability, mass variation, and residual content in both unaltered and alkali-modified bamboo fibers. The fibers were chopped into small pieces and ensured clean and free from contaminants. The experimental assessments were executed employing a thermal analyzer manufactured by Perkin Elmer. The test was conducted in a controlled atmosphere within an alumina crucible that featured a pinhole orifice, utilizing a consistent heating rate of 5 °C min^{-1} and under a nitrogen flux of 19.8 ml/min. Initial weight of the sample was measured as 8.303 mg for untreated fibers and 3.548 mg for the treated bamboo fibers. Thermogravimetric analysis (TGA) curves were generated for both untreated and treated bamboo fibers to elucidate their thermal degradation behavior as shown in figure 8. The TGA curves illustrate the relationship between temperature and the mass loss of the fibers. The untreated bamboo fibers exhibited distinct degradation patterns in comparison to the treated fibers, suggesting alterations in their thermal stability and decomposition characteristics. These TGA curves provide valuable insights into the impact of the treatment process on the thermal properties of the natural fibers. A temperature range was selected between 30 and 600 °C for the test. Three stages of thermal degradation such as initial mass loss, main decomposition and residue was clearly

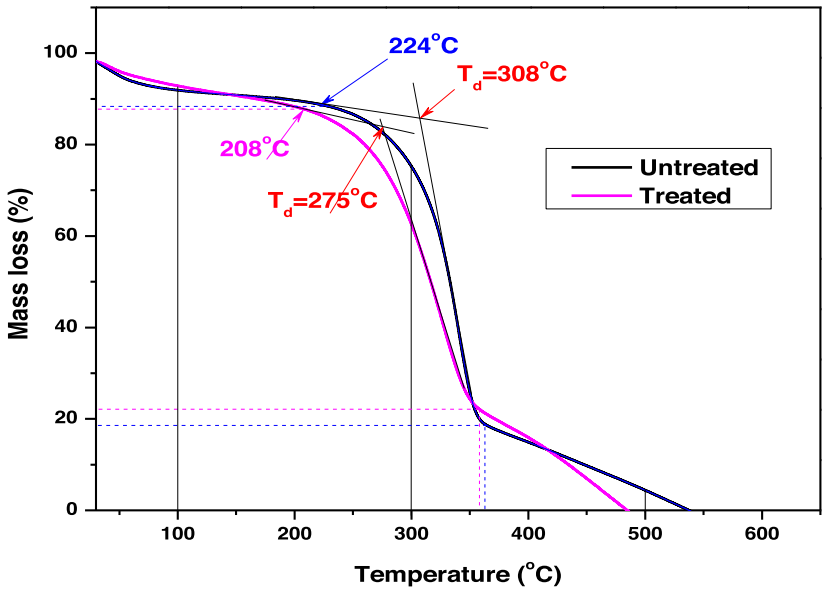

Figure 8. TGA of untreated and treated bamboo fibres.

Table 6. Comparison of thermogram results from different bamboo fibres obtained from various resources.

Fibre	Treatment	Mass loss (%)			References
		T_{100} °C	T_{300} °C	T_{500} °C	
Bambusa vulgaris	Untreated	5	15	80	[30]
Phyllostachys heterocycla	Untreated	8	20	80	[31]
Moso bamboo	Untreated	10	20	77	[32]
	Treated	3	15	75	
Bambusa Bambos	Untreated	8	25	94	Present work
	Treated	7	38	100	

observed in both the cases. An initial weight loss occurs due to the evaporation of moisture present in the sample. This can be seen as a gradual decrease in weight at lower temperatures. The initial mass loss of 7.65% was observed for the untreated bamboo sample at early stage of disintegration. The existence of moisture content was attributed to its natural occurrence, as generally common to all natural fibres. The main feature of interest is the major weight loss associated with the thermal degradation of the natural fiber's components. This stage might include the breakdown of cellulose, hemicellulose, lignin, and other constituents. For bamboo-treated fibre, a higher rate of weight loss of 60% was observed between 225 and 360 °C. This occurred due to the varying percentage of hemicellulose and lignin present in both treated and untreated fibres. A final weight loss of more than 80% was observed at 358 and 364 °C for treated and untreated samples shown in table 6 respectively. This phenomenon can be ascribed to the predominant degradation experienced by the cellulose and hemicellulose constituents within the fiber, resulting in the formation of char as evidenced by lignin's progression to this stage [29]. A comparable manifestation of thermal deterioration in bamboo fibers was also observed in a prior investigation involving bamboo fibers, as reported by Rajulu *et al* in 2002.

3.6. DSC analysis

Figure 9 illustrates the temperature-induced degradation phenomena as assessed through Differential Scanning Calorimetry (DSC) analysis, contrasting untreated and treated bamboo fibers. The DSC technique serves to elucidate the thermal decomposition dynamics of the inherent chemical constituents within natural fibers across varying temperature regimes, delineating the attendant heat flows in terms of inputs and outputs. Typically, the decomposition of plant-derived fibers across diverse temperature gradients manifests as a sequence of endothermic and exothermic events. These thermal transitions are manifested in the DSC profiles as discernible peaks, portraying the phase transitions of the fibers. Notably, in the temperature span of 10 to 120 °C, a conspicuous endothermic peak is evident, which corresponds to the liberation of moisture. This

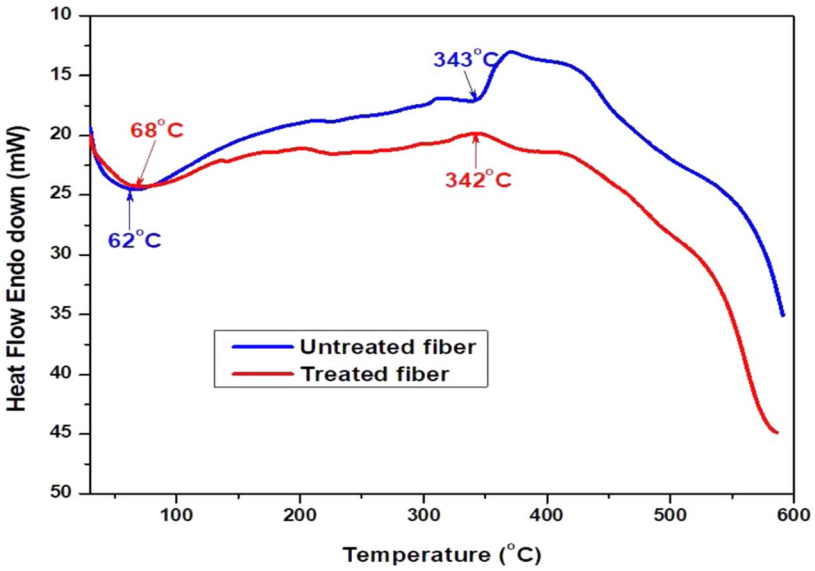

Figure 9. DSC curve for untreated and alkali treated bamboo fibres.

finding is congruent with analogous moisture evaporation indications deduced from Thermogravimetric Analysis (TGA) outputs.

The temperature range spanning 100 to 350 °C reveals a notable absence of exothermic or endothermic signatures, indicative of a thermally inert composite configuration. A further transition zone, ranging from 350 to 400 °C, is marked by a subtle endothermic peak discernible in the context of untreated bamboo fibers. This observation aligns with the decomposition of hemicelluloses, cellulose, and lignin constituents. In marked contrast, this distinct peak is notably absent in the treated bamboo fibers, a phenomenon potentially attributed to the enhanced structural organization of cellulose constituents resultant from the treatment process. Elucidation through Differential Thermal Gravimetric (DTG) profiles reveals that alkali-treated fibers and fillers share analogous peaks within the temperature bracket of 275 to 375 °C, indicative of partial hemicellulose elimination processes [33, 34].

4. Conclusions

The chemical, mechanical, thermal and morphological characteristics of both untreated and alkaline treated bamboo fibres have been investigated, using various techniques. From the results obtained, the following concluding remarks can be inferred. According to the chemical characteristics, the cellulose content of the fibres was much but wax, hemicellulose, lignin and other compositions were eliminated after treated the fibres with alkaline solution. The removal of these constituents was increased with the alkaline concentration. Physical examination established that the density and diameter of the treated fibres increased with the alkaline concentration. An XRD result reveals the increasing crystallinity index in the case of alkali treated condition which was 17% higher than the untreated bamboo fibre. Treated bamboo fibre recorded better or higher tensile properties than the untreated counterpart. Furthermore, it was evident through SEM micrographs that the reduction of fibre diameter and formation of fibril through debonding of weakly bonded chemical. This process could subsequently support to improve the interfacial bonding between the fibre and matrix in case of fibre reinforced polymeric composites. Besides, alkaline treatment increased thermal stability of the fibres. The highest weight loss and degradation zones of untreated and alkaline treated fibres were determined, using a TGA.

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Data availability statement

No new data were created or analysed in this study.

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