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Extraction and Effects of Mechanical Characterization and Thermal Attributes of Jute, Prosopis Juliflora Bark and Kenaf Fibers Reinforced Bio Composites Used for Engineering Applications

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Abstract: In the present work tensile, flexural, impact and hardness properties of Prosopis juliflora bark (PJb), jute fiber (JF) and kenaf fiber (KF) reinforced polyester composites are expressed for the first time. The challenge in working with natural fiber composites (NFC) is the large variation in properties and characteristics. The properties of NFC to an enormous degree are impacted by the sort of fibers, a natural condition where the plant fibers are sourced and the kind of fiber treatments. In this experimental investigation JF as a base material, PJb and KF are filler materials. The weight percentage of JF has been maintained as constant and the remaining two fiber fillers were varied. To investigate the mechanical characteristics of tensile, flexural, impact and hardness tests were performed as per ASTM standard. The mechanical test outcomes exposed a reliable propensity of an expansion in the above mechanical credits to including natural fiber fillers. Fourier transform infrared spectroscopy (FTIR) is utilized to identify the chemical composition of NF and SEM analysis utilized for interfacial adhesion between the NF and polyester matrix. Thermal consistency/degradation of NF was identified through Thermogravimetric analysis (TGA).

Keywords: FTIR, Flexural, Jute fiber, Kenaf fiber, Prosopis juliflora bark

Introduction

In the past decade, extensive research work has been carried out on the natural fiber reinforced composite materials in many applications. Natural fibers are available in abundance in nature and can be used to reinforce polymers to obtain light and strong materials. Natural fibers from plants are beginning to find their way into commercial applications such as automotive industries, household applications, etc. In structural and infrastructure applications, fiber composites have been used to rehabilitate existing structures such as bridges and buildings [1-3], especially those that are subjected to the marine environment or corrosive environment. Fiber composites also have been used for constructions that are exposed to different types of loading and environment. Examples of such are a windmill, roof, bridge, girder, railway sleepers, floating river walkway, monocoque fiber composite trusses, structural portal frames and truss system for deployable shelter [4-9]. Due to the need for more environmentally friendly materials, natural fiber composites are regaining the attention that once has been shifted to synthetic products. The first known utilization of natural fiber composites was straw reinforced clay for bricks and pottery [10]. Many of the early research and development in fiber composites are dominated using synthetic fibers. Although synthetic fiber composite materials such as glass fibers, carbon fibers and aramids are high performance materials, they are less biodegradable and are sourced from nonrenewable resources. Therefore, the use of natural fibers may bring environmental benefits as well as cost benefits. Jute is one of the most notable bast fibers and the second most regular common fiber developed on the planet (close to cotton) [11]. Jute fibers are fragile, with a low expansion to break because of the high lignin content (up to 12-16 %). Jute fibers have little protection from moisture, corrosive and UV light. Nonetheless, their fine surface just as their protection from hotness and fire has given a wide scope of uses in industries. Gopinath *et al*. [12] have studied the mechanical attributes for jute-epoxy and jute-polyester composites. They identified from the results comparison, the tensile and flexural strength of jute-epoxy composites are higher than jute-polyester composites and the impact energy of jute polyester is better than jute epoxy composites. Sathees Kumar [13] investigated the mechanical properties of sisal, jute and sorghum bicolor reinforced polymer matrix composites. From the results, the higher content of jute (40 %) enhanced the mechanical attributes such as tensile, flexural, impact and hardness. Jothibasu *et al*. [14] have recently investigated the hybrid composites using areca sheath fibers/jute fibers/glass fabrics reinforced in the epoxy matrix was laminated Hybrid areca sheath-jute-glass composites showed good tensile, flexural compression, and shear behavior followed by pure jute fibers-glass fabrics composite due to the presence of high strength jute fibers at their intermediate layers and good adhesion with resin. Kenaf is one of the NF utilized as reinforcement in polymer

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matrix composites (PMCs). Kenaf has been discovered to be a significant wellspring of fiber for composites, and other modern applications [15]. Kenaf is notable as a cellulosic source with both economic and environmental preferences. For the most part, the ductile and flexural properties of kenaf strengthened composites, differ contingent upon the sort of fiber, its direction, substance and structure (fiber or texture), and the kind of mixing/plasticizer utilized. For instance, Ochi [16] revealed that the ductile and flexural quality of kenaf rein-constrained PLA composites, increment straightly with fiber substance up to 50 %. Statically, the ductile and flexural quality of kenaf reinforced composites were around 223 MPa and 254 MPa, individually, in tests with a fiber part of 70 %. As per the outcomes got by this researcher, this demonstrated kenaf fiber shows higher qualities regarding ductile and flexural properties, when contrasted with other NF, while reinforcing PLA [17-19]. Hanan *et al*. [20] have identified the natural fibers bilayer hybrid composites were fabricated by a hand-layup technique by reinforcing oil palm empty fruit bunch (EFB) and kenaf fiber mats with epoxy matrix. Experimental results revealed that the tensile and flexural properties improved substantially on increasing the content of kenaf fiber to oil palm EFB composites, whereas the impact properties of pure EFB composite were much higher than those of hybrid composites. The PJF consisted of phloem fibers that belonged to the gelatinous or mucilaginous type as evidenced from the testing for bark anatomy. It also consisted of a highly lignified outer primary wall and a secondary wall that consisted of a mucilaginous substance and a cell lumen. The higher lignin content of the PJF can offer relatively higher rigidity in comparison to the existing bark fibers and relatively lower density of the PJF may enable lightweight applications e.g. textile and automobile industries [21]. The chemical properties of raw, alkaline and silane-treated Prosopis juliflora Fiber (PJF) and physico mechanical properties of PJF reinforced hybrid composites were studied. The silane treated PJ fiber is a good candidate to be used as a reinforcement in fiber composites [22]. The PJFs possess desirable tensile properties that make them an ideal alternative reinforcement material to the conventional fibers such as glass and carbon in polymer matrices. A comprehensive study that thoroughly investigates the effect of various factors on the mechanical properties of PJb composites is lacking in the literature and mechanical properties of PJb not yet discussed. The knowledge gaps outlined above show that the mechanical properties such as tensile, flexural, compression, impact and hardness of NFC reinforced with polyester must be characterized based on a wide range of underlying factors, such that their engineering application can be possible. It is anticipated that the findings will provide useful design inputs for making a new generation of NFC suitable for industrial, automobile and structural loading applications of civil engineering. In this work, three different natural fibers were extracted and utilized to identify the effects of mechanical attributes such as ductile, tensile, impact and hardness. Interaction between fibers and polyester matrix can be observed through a scanning electron microscope (SEM). Fourier transform infrared analyses are used to determine the chemical compositions of natural and modified natural fibers. Furthermore, the thermal stability of the NF composites was also investigated through thermo-gravimetric analysis (TGA). Finally, this study indicated that alkali treatment on natural fibers enhanced the mechanical attributes and thermal consistency of the fibers.

Experimental

The materials used in this experiment for fabrication are Prosopis juliflora bark, jute fiber, and kenaf fiber. The PJb, kenaf and jute fibers are collected in the form of residues from Ramanathapuram district, Tamil Nadu, India. Cobalt Naphthenate as an accelerator agent and Methyl ethyl ketone peroxide (MEKP) as a catalyst is procured from M/s. Supreme scientific Ltd., Madurai, India. The polymer utilized in this work improvement was unsaturated terephthalic polyester resin in the pre-quickened structure, created by Royal Polímeros under the business name of Denverpoly 754. The Cobalt Naphthenate was included as 2 % with the resin and the catalyst around 2 to 3 m*l*.

Extraction Process of Fibers

Bark from Prosopis Juliflora Tree

The PJ plant has a twisted stem and flexible branches with long and strong thorns. The roots penetrate to great depths in the soil and can grow in a wide range of soils, such as saline, alkaline, sandy and rocky soils [23]. It occurs worldwide in arid and semiarid regions [24]. The PJb of this plant acted as the source of natural fiber. The size of barks approximately 20 mm length and 10 mm thickness. The inner layer was removed and disposed of while the outer layer was retained for subsequent separation of barks.

Fibers from the Jute Plant

Jute fibers are cut into 4-5 cm in length are washed with distilled water. They were dried during 3-4 h. Then, the fibers are soaked in the 5 % concentrated NaOH solution for 24 h at 30 °C, after which the fibers are washed with distilled water to remove the presence of NaOH sticking in the fibers. The fibers are then allowed to dry for 6-8 h at room temperature.

Fibers from the Kenaf Plant

The extraction of the fiber from the Kenaf plant was completed by water retting measure. The stem of the kenaf plants was lowered in a water shower and secured with water hyacinths for 26 days. At long last, the filaments were cleansed appropriately and dried under shade and saved prepared for additional utilization [25].

Alkaline Treatment of Natural Fibers

Alkaline treatment is a typical fiber surface treatment that can likewise be utilized as a pre-treatment when joined with

other compound adjustments. Initially, these treatments were completed to improve fiber's dye liking and luster [26]. Researchers thusly found that alkalization likewise positively affects the mechanical attributes of fiber-strengthened composites, yielding noteworthy upgrades in the interfacial performance [27,28]. The surface treatment of the strands was finished utilizing alkali treatment to improve its quality. The strands with equivalent weight proportion were absorbed 5 % of NaOH focuses for 4 h with manual mixing at each 30 min were washed in refined water and dried at room temperature. The low-thick polyester resin of business grade methyl ethyl ketone peroxide and Denverpoly 754 making some gel memories of 120-180 min is utilized as a matrix material.

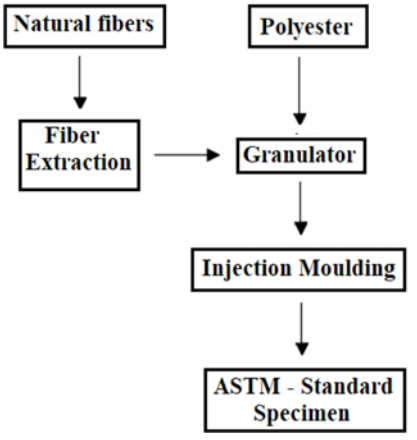

Figure 1. Flow chart of specimen preparation.

Fabrication of Samples Through Injection Moulding

The natural fibers were about 3-3.5 m long. To ensure an easy blending, they were chopped into short lengths. The chopped fibers and polyester were then compounded. The mixed blends were moulded into ASTM standard specimens by an injection moulded at a moulding temperature of 185 °C. Natural fibers and polyester were mixed by injection moulding machine. The NF were initially dried at 70 °C in an air circulating oven for 24 h before mixing. The extruded NF granules were dried again 80 °C for 24 h (water content < 1 %) before the specimen preparation by the injection moulding process. Test specimens were prepared from dried NF granules by the injection moulding process at melting the temperature about 160-185 °C in an injection pressure 87 bar. A flow chart of specimen preparation as shown in Figure 1.

Granulated material was dried in a stove at 70 °C for 2 h before injection moulding. This is to forestall the arrangement of air rises in the samples which may bring down their mechanical attributes. The materials aggravated were injection moulded into ductile test samples, utilizing an Injection forming machine. Table 1 shows the injection moulding

Table 1. Operating parameters on the injection moulding machine

Factor, set point temperature (°C)	Pressure zone (bar)	Time (s)
Barrel - 210	Injection pressure - 87	Injection time - 10
Melt - 185	Hold on pressure - 65	Cooling time - 25
Mould - 23	Back pressure - 14	

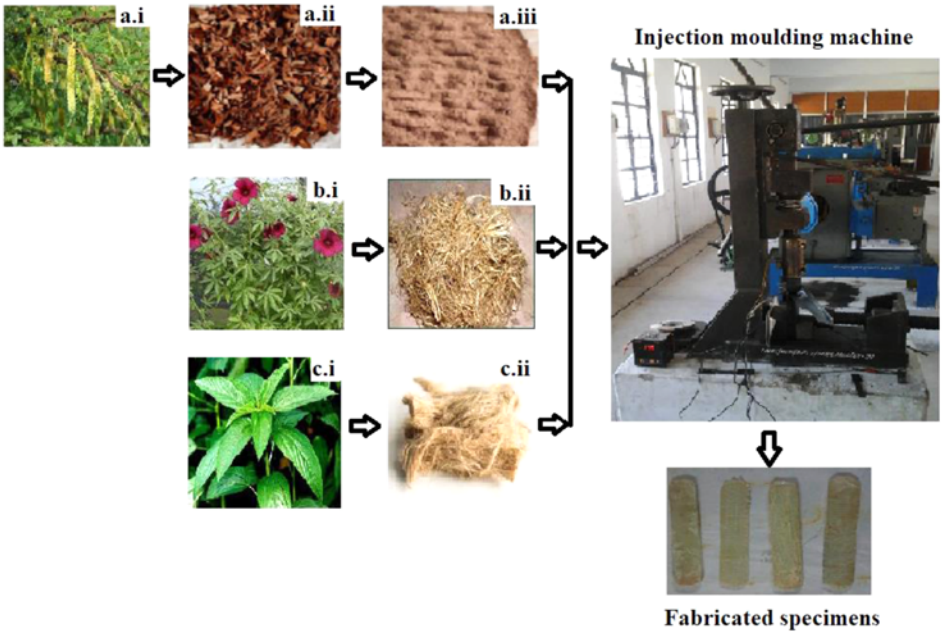

Figure 2. Fabrication process of natural fiber composites through injection moulding; (a.i) PJ tree, (a.ii) PJ bark, (a.iii) PJ bark powder, (b.i) kenaf plant, (b.ii) KF, and (c.i) jute plant, and (c.ii) JF.

Table 2. Composition and designation of composite specimens

Natural fibers (weight %)			Designation of samples
JF	PJb	KF	
50	40	10	A
50	30	20	B
50	25	25	C
50	20	30	D
50	10	40	E

machine set boundaries for the fiber/Polyester composites. The natural fibers and polyester resin were mixed and put into the injection moulding machine. The blended materials flow through the moulding chamber and it was poured in a rectangular formed shape (160 mm×140 mm×4 mm) under a tension of 10 MPa and at a temperature of 190 °C for 10 min. A similar weight was kept up for 15 min during the cooling stage. The materials compacted were shaped as level test examples. Table 2 shows the composition of composites. The fabrication of composite specimen as shown in Figure 2.

Materials Characterization

Tensile Strength

Thetensile strengthof a material is the maximum amount oftensile stressthat it can take before failure, for example breaking. In order to test properly, specimens must be held perpendicular to the jaw faces and not tilted on an angle. Specimen misalignment can cause major variations in results, and proper care should be taken to ensure that the specimens are all aligned consistently for each test. One way of addressing misalignment is by using a jaw face that is close to the same width as your specimen, making it relatively easy to visually adjust alignment. But the easiest way to prevent misalignment is to use a specimen alignment device which mounts directly onto the grip bodies. This is a simple bar that provides an adjustable stopping point so operators can easily tell that their specimen has been aligned correctly. Furthermore, load the specimen into tensile grips and attach the extensometer to the specimen. Begin the test by separating the tensile grips at a constant rate of speed. The speed depends on specimen shape and the range form 0.05-20 inches per minute. The target time from start of test to break from 30 seconds to 5 minutes. When the grips are tightened onto the plastic specimens in preparation for running a test, unwanted compressive forces are frequently applied [29]. These forces, although minute, can interfere with test results. The fabricated NF composite tensile specimen as shown in Figure 3.

Flexural Strength

Flexural strengthis the amount of force an object can take without breaking or permanently deforming. In this experiment, a 3-point bending method is used for finding out the flexure of a specimen. Flexural tests have been conducted by the same tensile testing machine. The size of the specimen for the flexural test is 110×15×3 mm according to ASTM D790. This fixture consists of a loading nose attached to the moving crosshead and a fixed member with two specimen supports, or anvils, which can be adjusted to fit the distance of the specimens' support span. The surface of the anvils and loading nose should be cylindrical and have a radius of 5 mm unless otherwise specified, and the length of the cylindrical member should be longer than the width of the specimen. The 3-point flexural test is the most common flexural test and used in this experiment for checking the bending strength of the composite materials with a support span length of 70 mm and the test speed is 0.05 to 0.1 in/min and adjustable span distance of 10-200 mm. The testing process involves placing the test specimen in the UTM and applying force to it until it fractures and breaks. The measurements were taken at five magnitudes of the constant load for all specimens. The fabricated NF composite flexural specimen as shown in Figure 4.

Figure 3. NF composite tensile specimen.

Impact Strength

The ability of a material to absorb mechanical energy in the process of deformation and fracture under impact

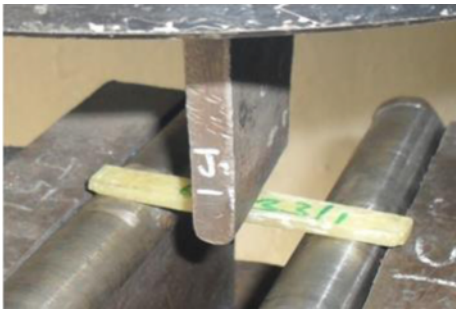

Figure 4. NF composite flexural specimen.

Figure 5. NF composite impact specimen.

loading. The impact test is conducted on a Tinius Olsen testing machine and the test specimens are prepared according to the required dimension following the ASTM-D 256 standard. The Izod test specimen as per dimensions are 65 mm×15 mm×3 mm. The Izod impact test consists of a pendulum with a determined weight at the end of its arm swinging down and striking the specimen while it is held securely in a vertical position. Izod normally refers to anotched specimenimpact. the notch is placed in the clamp and a pendulum is released that impacts the bar, measuring the energy required to break the sample. How tightly the specimen is clamped in the holder plus any flash or defects in the injection-moulded specimen can affect the results [31]. During the testing process, the specimen must be loaded in the testing machine and allows the pendulum until it fractures or breaks. Using the impact test, the energy needed to break the material can be measured easily and can be used to measure the toughness of the material and the yield strength. The effect of strain rate on the fracture and ductility of the material can be analyzed by using the impact test. The fabricated NF composite impact specimen as shown in Figure 5.

Hardness

The hardness test is conducted on a Shore D hardness test machine (Model SRT-102). The ASTM D2240 standard specimen is carried out in the shore (Durometer) hardness tester (Make, Hiroshima, Japan). Each hardness test specimen is prepared for the size of 35 mm×15 mm×3 mm [32]. The device consists of a hardened steel rod with a truncated cone at the tip. The steel rod is spring-loaded and actuates a dial with a scale of 0 to 100. The test specimen is placed directly underneath the truncated cone, and the device is pressed down onto the part until the flat metal plate on the bottom is flush with the rubber specimen. The more the cone deforms the rubber material, the lower the hardness measurement. The less the cone deforms the material, the higher the hardness measurement.

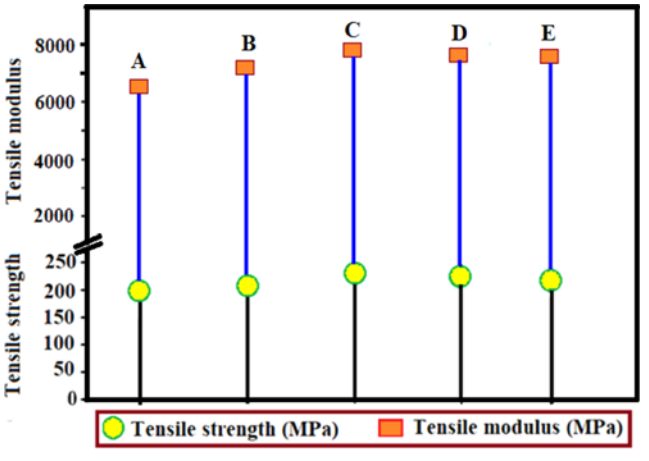

Figure 6. Tensile properties of NF composites.

Results and Discussion

Tensile Attributes

It can be observed from Figure 6. that the tensile strength and tensile modulus of the polyester composite increase with natural fiber loading in all cases. The alkali treated composites A, B, and C show gradual enhancement of ductile strength. The hybrid composites exposed a better effect up to the weight % of JF (50 %), PJb (25 %) and KF (25 %) in specimen C. From the Figure 6. when the equal weight of fiber contents of JF and KF are extended the tensile strength and tensile modulus of the composites. From the results, equal weight % of the JF and KF contents hold and enhanced the ductile attributes of natural fiber composites. In D and E specimens, the ductile strength was gradually diminished, due to the low addition of (20 % and 10 % PJb) fibers. However, the higher inclusion of KF also responsible for negative effects. Higher contents of KF (30 and 40 %) swapped the better ductile attribute into brittleness. The experimental results of specimen C have enhanced the overall ductile behaviour compared with other specimens, such as A, B, D and E. The comparison values are observed in percentages are 8.37 %, 5.24 %, 2.68 %, 3.33 % respectively. Furthermore, the tensile modulus of NF composites was enhanced steadily from A, B, and C specimens. In D and E specimens the modulus has been diminished, higher inclusion of KF and low inclusion of PJf enhanced the brittle attribute. The strength was decreasing due to the inability of the fiber to support stresses transferred from the polymer matrix [33,34]. The tensile modulus of specimen C compared with remaining specimens such as A, B, D and E. The comparison modulus values are studied in percentages 23.34 %, 10.06 %, 3.60 % and 6.4 % respectively.

The elongation of composite specimens is shown in Figure 7. The elongation attributes gradually enhanced from specimens A, B and C. The development of elongation characteristics of specimens proved the well-behaved interfacial link between the fibers and polyester matrix [35]. Specimens D and E gradually downgrading the elongation at

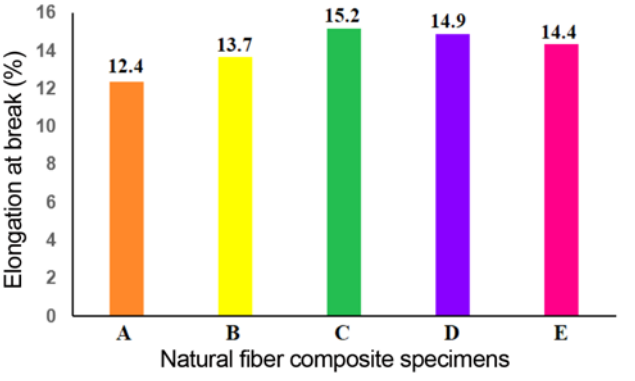

Figure 7. Elongation at break of NF composites.

Figure 8. Tensile fractured specimen.

break. Increasing the kenaf fiber contents in the specimen D and E, the elongation holding nature of fiber may be distressed. The tensile fractured specimen as shown in Figure 8.

Flexural Attributes

From Figure 9 that the flexural strength of the polyester composite intensifies with natural fiber loading in all samples. The composites A, B, C, D and E show gradual enhancement of bending strength. Figure 9 indicates that the low content of PJb and high amount KF fibers to the polyester improves the flexural strength and the deflection on specimens D and E. Better holding zones among fibers and resin and no indications of fibers debonding, separation or pull out systems at the treated NF composite crack surface after flexural stacking. This outcome proposes that interfacial attachment between the three fibers and the polyester matrix has gotten significantly more positive and endless supply of fibers with NaOH. Flexural properties are also enhanced with filler addition [36].

Furthermore, the flexural modulus of composites as shown in Figure 10. As the KF content goes upto 40 %, the flexural modulus develops noticeably in polyester reinforced composites. This enhancement is a clear indication of better effective load transfer between the polyester matrix and fibers. Stress transfer of the composites increased by strong fiber and matrix bonding, allowing elastic deformation [37]. It is subsequently evident that the alkali treatment fundamentally expands the elasticity of NF composites. Flexural fractured composite specimen as shown in Figure 11.

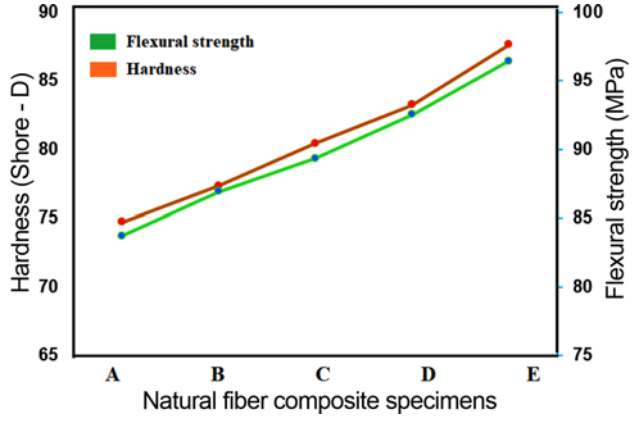

Figure 9. Flexural strength and hardness of composite specimens.

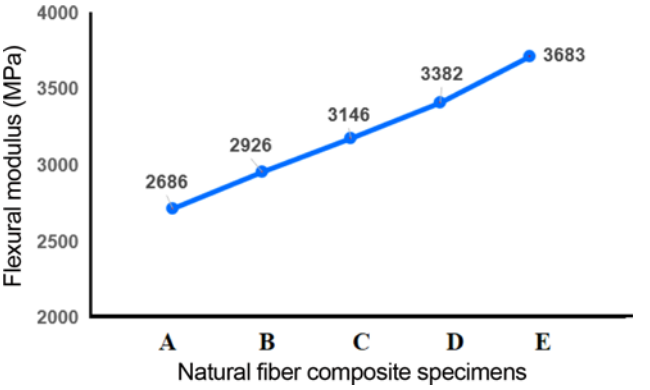

Figure 10. Flexural modulus of composite specimens.

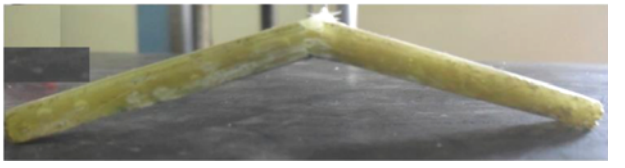

Figure 11. Flexural fractured composite specimen.

Hardness

Figure 9 represents the hardness values of the jute/kenaf/PJb composites. Alkali treated fibers reveals the rapid enhancement of hardness values. In specimen A it has a low value 71.4 then it has progressively enhanced upto 83.7 on specimen E. The higher content of kenaf and the low addition of PJb of (40 % KF and 10 % PJb) natural fibers boosted the hardness attributes of the polyester composites [38]. The reason for increasing the hardness is the better dispersion of fibers into the polyester matrix stronger interfacial adhesion to the fiber matrix.

Impact Strength

Figure 12 the impact of composites enhances from A, B, C, D and E progressively. The weight of kenaf fiber (40 %) and PJ (10 %) bark powder is extended the extreme impact of about 29 J/m^2. Specimen E compared with other specimens like A, B, C, and D were attained a better impact of 26.08 %, 16 %, 14.8 %, 11.5 % and 7.4 % respectively.

The expanded fiber substance will augmentation the contact surface between the fiber and matrix if there is acceptable impregnation of filaments in the resin. At higher fiber stacking the effect, move ought to be more proficient [38]. Significant attachment between the fiber and polyester matrix is too liable for the great protection from break spread during impact tests. Fractured impact specimen as shown in Figure 13.

SEM Morphology of Tensile Fracture Surface of the Natural Fiber Composites

The inside attributes of the normal fiber composite

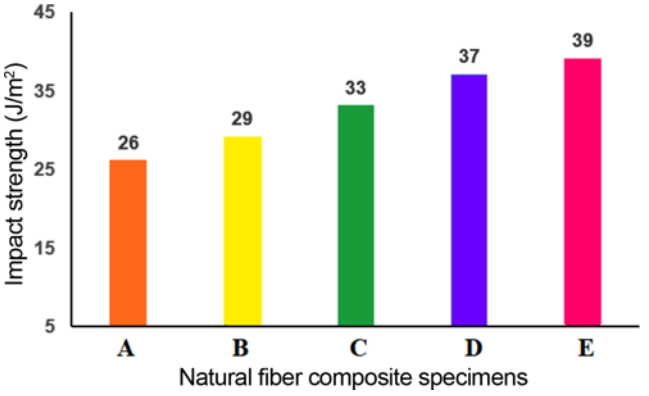

Figure 12. Impact strength of composite specimens.

Figure 13. Impact fractured composite specimen.

material used for the assessment are examined accordingly of SEM. Sem images are taken for two composite specimens C and D. The C specimen attained progressively maximum tensile strength and the D specimen arrived at a sudden diminish. Due to this controversy results, the C and D specimens were utilized for SEM. Figure 14(a). Represents the tensile fractured morphology image of C specimen. In this image, voids, fiber pullout and clean fiber surfaces were observed clearly Due to the proper blending of three natural fibers with polyester matrix, only a few voids and small fiber pull out have been observed. Proper interlinking adhesion between fibers and the polyester matrix also responsible for enhancing the ductile attributes.

The fiber pull-out is noticed in Figure 14(a). It is recognized from the crack surface images of three natural fibers and mixture polyester composite that there is the composite failure during the ductile test due to debonding and the fiber pull out. Less fiber pull out and enhanced bonding/adhesion at the fiber/matrix with the increased fiber loading could be seen in Figure 14(a). Thus, the increased fiber content in the composite helped to distribute the load effectively within the matrix, thereby leading to improved tensile strengths/modulus in the specimen C composites compared to specimen D. Figure 14(b). Exposes the morphological image of specimen D. The image reveals the

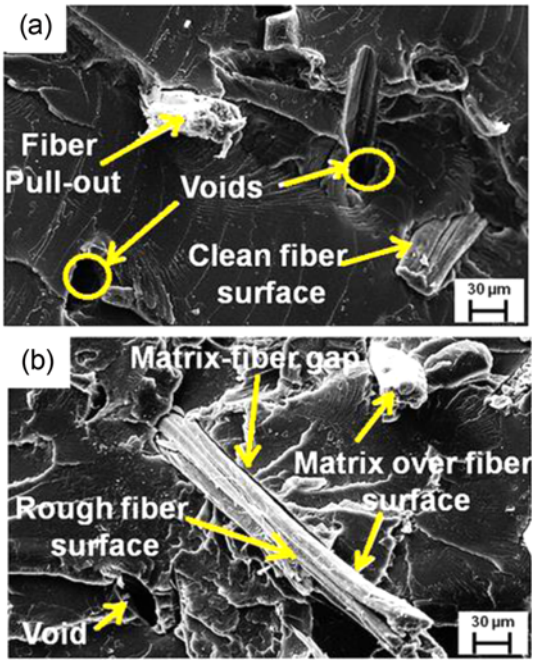

Figure 14. SEM images of tensile fractured specimens; (a) specimen C and (b) specimen D.

voids, matrix fiber gap and fiber pullout. As appeared in Figure 14(b), there was no interrelation between the NF and the matrix, even despite of a limited quantity of polyester presentation into the interface locale. The disappointment mechanism for this composite was fiber-matrix debonding. This shows there was an absence of fascination between the NF and the polyester, affirming the need of upgrading the fiber/polyester interface. This can be seen by the appearance of matrix fiber gaps between the polyester and fiber surface, as shown in Figure 14(b).

FTIR Spectroscopy

FTIR investigation was completed to appraise the effect of chemical treatment on the fibers. The characteristic peak 3963.2 cm^{-1} in Figure 15 speaks to the presence of O-H bunch extending in the cellulose of jute and kenaf fibers. The normal pinnacle of 3467.14 cm^{-1} refers to O-H extending of the hydrogen bond in the treated PJb, JF, and kenaf fibers. In any case, one more attribute top at 2867.18 cm^{-1} of C=H stretch in the alkane of the treated sample. The presence of this pinnacle demonstrates the expulsion of waxes and different contaminations from the jute and kenaf fiber surface. The removal of this layer resulted in better interaction adhesion between the matrix and the fiber [39].

The high spot of 2361.53 cm^{-1} indicates the CN extending in the nitrile group. The specific top at 1441.36 cm^{-1} mentions to C=C extending in aromatic groups in the cellulose and hemicellulose of treated jute and kenaf fibers. The Alkyl halide gathering (C-Cl) of lignin may be credited to the

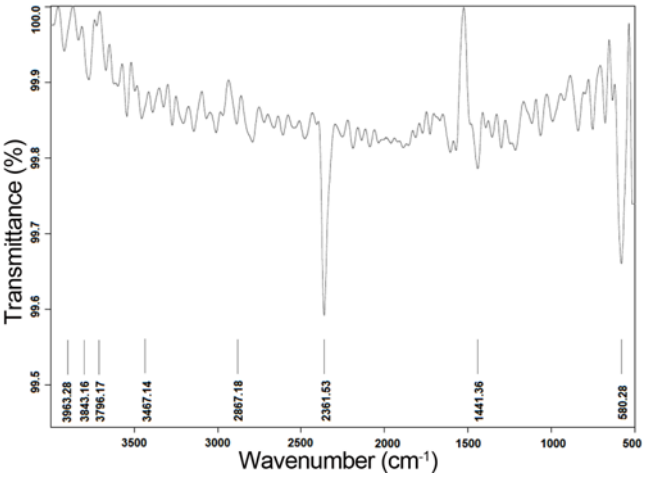

Figure 15. FTIR spectroscopy of flexural specimen E.

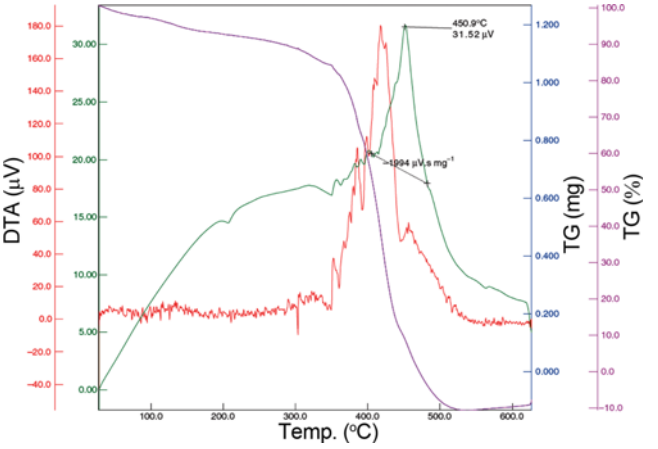

Figure 16. TGA of flexural specimen E.

typical top predicted at 680.28 cm^{-1}. Furthermore, the feature crests at 1042 cm^{-1} are allotted to C-O extending in the glycosidic linkage of the cellulose. In this way, the chemical composition of the examples shows no variety in substance bonds.

Thermal Stability/Decomposition of Natural Fiber Composites

Thermogravimetric investigation (TGA) is a valuable procedure for the investigation of the thermal strength/ deterioration of NF composite materials. The thermal stability of the fiber is a significant boundary for the preparation and utilization of these materials. The assembling of such composites needs the blending of fibers and matrix at elevated temperatures, so the degradation of the cellulosic materials can deliver bothersome impacts on the attributes. Various exploration articles have concentrated on the investigation of the thermal dependability of natural fiber plastic composites through TGA. The amount of weight reduction of the sample as an element of temperature estimated to anticipate the thermal conduct of the material.

TGA treated natural fiber was studied as a function of percentage weight loss with an increase in temperature. The mass loss increases with temperature, for a heating rate of 10 C/min, were shown in Figure 16. The treated NF indicated a comparative pattern of deterioration with one phase of weight reduction measure, which had a progress temperature that started from 247 to 352 °C and the range for definite change at 375-415 °C. From a room temperature until 32 °C, the TG thermograms present the loss of mass because of the water vaporization heat in the example. It is generally acknowledged that the essential warm decay of the cellulosic parts materials happens somewhere in the range of 200 and 400 °C [40]. The underlying decay of the cellulosic segments happens generally in the amorphous regions [41]. Moreover, from TGA bends it is obvious that the temperature at which dampness began to be freed was higher for salt treated samples. This perception can be clarified based on changes happening in the fine structure and morphology of NF strands because of antacid treatment. Thusly, the propensity to free ingested dampness after warming will diminish, as dampness is unequivocally held inside a firmly pressed structure, prompting a higher completed temperature. It is reported that in cellulose fibers, lignin degrades at a temperature around 200 °C while the other polysaccharides such as cellulose degrade at higher temperatures [42]. In light of these outcomes, the warm strength of lignocellulosic materials was expanded by the alkali treatments. This could be credited to the evacuation of hemicellulose and lignin during the alkaline treatments, just as to the further extent of crystallinity in the material after mechanical processing. The alkaline treatments were accepted to degrade the amorphous area in the cellulose and increment the level of crystallinity [43]. Therefore, the more prominent crystalline structure prompted a high obstruction towards warmth and increment in the greatest temperature for thermal degradation. Thermal debasement is additionally a significant aspect of the improvement of NF composites since it will emphatically influence the greatest temperature utilized in the preparation composites. The degradation of NF prompts poor organoleptic attributes, for example, odor and shading and crumbling of their mechanical properties [44].

Conclusion

The extraction of JF, PJb, and KF, alkaline processing and mechanical properties of the NF hybrid composites were explored. From the experimental investigation of mechanical attributes, characterization and thermal stability of bio composites, the following conclusions were drawn:

The mechanical attributes such as, tensile, flexural, impact and hardness on natural fibers reveal that the mechanical properties of alkali treated fibers are superior in the polyester

matrix. Very good adhesion between the NF and polyester matrix enhanced the ductile properties and proper dispersion of Pjb, jute and kenaf fibers attained the maximum flexural attributes. Furthermore, the addition of kenaf fibers developed the overall hardness and impact strength in the natural fiber composites. SEM and FTIR analysis also exposed the fiber bonding and chemical composition of fibers. TGA reveals the initial and final degradation temperatures for natural fibers were measured in the temperature range 32-550 °C. From these values, it can be concluded that the thermal stability of the fibers was improved by alkali treatment. These types of composites can be useful for different engineering applications (automotive and industrial domains).

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