Mechanical and Thermal Characterization of Composite Material Using Paddy Straw Fibre

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Abstract - Fibre from paddy straw is one of the waste products in agriculture. The way to lessen the negative consequences of burning paddy straw, such as air pollution and environmental problems. In an attempt to lessen the environmental effect of paddy straw, efforts are being undertaken to identify good and sustainable uses for it. Investigating the technology for turning agricultural waste into creative items is the research gap. In this work, ortho laminated polyester composites reinforced with paddy straw fibre are used to form the composites. An alkali handling is applied to the paddy straw fibre to boost its strength. The raw and treated fibre were characterised by X-ray diffraction, Fourier Transform Infrared Radiation, Thermogravimetric Analysis, and surface images. The 300x300x3 mm randomly oriented composite laminate was created using semi-automatic compression moulding with weight ratios of 70:30, 60:40, and 50:50 (untreated and treated). After the laminate was prepared and cut according to the ASTM standard, the specimens were broken to employing a scanning electron microscope to determine the shape and structure, as well as the mechanical behaviours (tensile, flexural, impact, hardness, and shear). Ultimately, the results demonstrate that the fibre from paddy straw is an excellent material for non-structural uses.

Keywords: Paddy straw, Polyester resin, Characterization, Mechanical properties, Morphology study.

1. INTRODUCTION

Natural fiber-based composites are becoming more and more popular as a result of the biodegradable properties and plentiful availability of fibre sources. Natural composites offer a workable way to lessen the environmental pollution brought on by synthetic materials as a sustainable substitute for non-biodegradable fiber-based goods [1]. Expert knowledge of the greenhouse effect, climate change, and global warming has increased efforts to promote environmental friendliness and energy efficiency. Due to their environmental friendliness, natural waste products from industry and agriculture, especially those containing natural fibres, have come to the attention of researchers due to this influence. Researchers need to know these wastes' physical, mechanical, and thermal qualities in order to evaluate the best ways to use them and profit from them while minimizing the risks that come with burning or letting them break down in the open. [2] Natural fibre composites, also known as natural fibre toughen composites, have become more well-known lately due to its application in a range of environmental settings. A few benefits of natural fibres over synthetic ones are that they are low in density, affordable, non-abrasive, biodegradable, and need less energy to produce.

In order to meet the goals of the research project, an extensive literature review was conducted to determine the most current developments in natural fibre composites across a range of industrial uses. As a result, a literature review was compiled on research topics such the reinforcing of natural fibres and surface treatment impacts on natural fibre composite characteristics. Muthu et al. (2022) characterised the chloris barbata flower fiber/epoxy composites with the fibre treated with alkali using a variety of methods, such as thermogravimetric analysis (TGA), Fourier transform infrared analysis (FTIR), scanning electron microscopy (SEM), and atomic force microscopy (AFM) [3]. The mechanical features of polymer matrix composites increased with rice straw fibre were examined by Ismail et al. (2011) [4]. Fibres from rice straw were extracted from agricultural waste. Using a locally made shatter machine, it is cleaned and broken into little pieces before being utilised. Once ground, the fibres were sorted via a sieve according to size; they had diameters between 1.25 and 0.85 mm and lengths between 20 and 8 mm.

According to Ming et al. (2011) [5], studies were conducted on the crystallisation behaviour of high-density polyethylene composites reinforced with fibre from paddy straw. The aspect ratios of refined fibre and rice straw strand were greater, at 14.48 and 16.31, respectively. Dinh et al. (2018) suggested that due to the low thermal characteristics of Cellulose fibers, the thermal stability of Polypropylene was reduced when Cellulose fibers were loaded to a higher level, yet the temperature of their 10% weight loss was found to be higher than 300°C [6]. Kamel et al. (2004) found that the composites made from rice straw treated with NaOH at 80°C had the highest bending and tensile strengths [7]. The PWG and swell ability percentage of composites produced by pre-treating with water at 130° C, however, a little lower than those produced by other pre-treatments. In comparison to untreated composites, coupling agent-treated composites have better mechanical and dimensional stability. These characteristics become greater as the concentration of lignin climbed.

By examining the mechanical and wear rate of the finished laminate, Irullappasamy et al. (2018) examined the increased surface quality of palmyra fruit fiber-reinforced polyester composites made possible by the NaOH treatment [8]. This was done in comparison to other chemical treatments. In polyester composites reinforced with raw fibre, the primary causes of fibre failure have been determined to be fibre debonding and fibre cracking. [9] Ali-Eldin et al. (2021) examined the use of glass fibre into the reinforcing of paddy straw has gradually enhanced the physical properties of the composite materials. For two days, or forty-eight hours, the paddy straw fibre was immersed in a 2% NaOH solution. The epoxy composites' dynamic and static mechanical characteristics were investigated using a 15% NaOH concentration that is appropriate for Phoenix SP fibre. (10) The impact, tensile, and flexural characteristics of chitosan, rice husk, CG fiber-epoxy composites, and red mud were reported by Jeyapragash et al. (2020). Fiber-reinforced composites using Calotropis gigentea fibre showed tensile, flexural, and impact test values of 64.3 MPa, 80.3 MPa, and 56.2 kJ/m^2. Tensile, flexural, and impact strength maximum values were 43.54 kJ/m^2, 60.53 MPa and 121.09 MPa for the specimen with a 100 mm fibre length and 40% fibre weight percentage, respectively. By using a scanning electron microscope, Jayabal et al. (2011) demonstrated that, in contrast to the coir-polyester matrix, the fabric glass and polyester resin generated an excellent interfacial bonding during the fibre pull-out, which began with natural fibres before moving on to glass fibres [11]. According to research by Rajesh et al. (2020), as fibre length, volume percentage and immersion temperature increased, so did the loss of flexural and tensile capacities [12].

In polymer matrix composites, paddy pulp is found in novel locations according to Singh et al. (2014) [13]. Various table-size models and floor furnishing materials are made with it, among other things. According to Motaleb et al. (2022), using compression moulding to strengthen polypropylene composite with chemically treated pineapple fibre (25–45% weight percentage) has an influence [14]. Results show that when compared to other composite preparations, formulations made with 45 weight percent pineapple fibre had improved tensile, bending, and impact strength. Balasubramanian et al. (2016) examined the input parameters of feed, speed and depth of cut as well as the output replies of torque and thrust force for the drilling operations [15]. The models and experimental data showed a strong correlation, with average errors of 0.77% and 1.22%, respectively. An examination of the wear features of epoxy composites reinforced with abaca fibre and red mud filler was conducted by Sinha et al. in 2020. The influence of weight percentages of abaca, red mud, and red mud particle size on hybrid composites' sliding wear may be optimised by the use of a mathematical model [16]. Peng et al. (2019) pretreat rice straw with diluted acetic acid [17]. The pretreatment procedure was able to remove the lignin layers from the rice straw, as seen by the disordered fbers with cusps on the surface of the treated straw, in contrast to the smooth and well-ordered fbers of the untreated rice straw.

[18] A technique of extracting cellulose from rice straw with the use of chemical ultrasonography was proposed by Yuan et al. (2020). When the temperature was high, a high concentration alkaline treatment was used. Granules with a mean diameter of 5 μm and a significant degree of roughness were produced. The methods of twin-screw extrusion and rotary steaming digestion/defibration for extracting fiber from rice straw were compared by Theng et al. (2019) in order to manufacture fiberboards [19]. Comparing the twin-screw extrusion technique to

the digestion/defibration process, the former requires significantly more energy consumption, despite its higher starting cost. The digestion/defamation process uses 8.52 kW h/kg and twin-screw extrusion uses 0.946 kW h/kg of specific energy respectively.

In order to address the shortage of solid wood in the wood sector, Yang et al. (2003) turned rice straw into insulating boards [20]. Commercial binder was combined with rice straw to give it a certain strength and form. Between 1000 Hz and 8000 Hz, the average absorption coefficient is determined to be 0.5. Sanjay et al. (2015) studied the effects of adding graphene fibre reinforcement (GF) to sisal polypropylene composites. Improving the tensile and flexural characteristics had no effect on the tensile and flexural modulus. According to Rozali et al. (2017) [22], hybrid composites with glass fibre (GF) mat on the exterior and kenaf (KF) mat on the inside had the maximum flexural strength and modulus. The effects of hybridising glass fiber-reinforced epoxy with rice straw were studied by Ali-Eldin et al. in 2018 [23]. The elimination of synthetic and natural contaminants by alkali treatment, according to the scientists, increases fiber/matrix adhesion. Hybridization plays a major role in making it feasible to comprehend and decide which material is best for the necessary design and development.

A. Motivation and Objective

Remaining crop residuals are produced in significant quantities by agricultural crops, and as food production rises, so do crop residues. These residual leftovers show both the depletion of resources and the passing up a potential to rise a farmer's revenue. Researchers from all around the world are looking at how agricultural waste may be used in a range of sectors, such as animal feed, biogas production, electricity generation, compost and manures, and the manufacturing of non-woven textile composites. Crop residue in agriculture has a competitive potential because to the growing trend of adding bioenergy cogeneration facilities, the growing need for animal feeding and the growing trend of organic agriculture. This study's primary objective is to to develop the composite material which reinforced using paddy straw fiber. The mechanical, thermal and structural morphology has been conducted for various proportion of raw materials.

II. MATERIALS AND METHODS

The fibre reinforced polymer composite method to be followed in this research i.e., combination of matrix and reinforcement. Here polyester resin has been chosen as matrix and paddy straw as reinforcement. When rice is harvested, rice straw is created as a byproduct. Depending on whether it was harvested by hand or by machine, rice straw is taken out of the field together with the rice grains and is then heaped or strewn out. Depending on the species and growing stage, the ratio of straw to paddy might vary from 0.7 to 1.4. In addition to contributing to air pollution, burning paddy straw results in the depletion of vital nutrients and soil organic matter, lower microbial activity, and increased susceptibility of the land to soil erosion. Similar in strength to linen fibres, rice straw fibres have a cellulose content of 64% with 63% crystalline cellulose, an elongation of 2.2%, and a modulus of 200 g/denier (26 GPa). Rice straw's 38% cellulose, 25% hemicellulose, and 12% lignin composition make it a lignocellulosic biomass. In contrast to other plant biomass, including softwood, rice straw has more hemicellulose and less cellulose and lignin.

Polyhydric spirits and dibasic organic acids react to generate polyester resins, which are synthetic resins. Unsaturated polyesters (UPR) are employed in a wide range of industrial industries, they are most frequently utilised as a matrix material in different kinds of composites. When polyester and glass fibre are mixed, their mechanical qualities improve significantly. The composite is joined by resin and gains mechanical strength from natural fibre, which serves as an inexpensive reinforcement phase in the polyester matrix phase. Cobalt octoate (VBR 1201) and methyl ethyl ketone peroxide (VBR 1204), an accelerator, are required to start the curing process. Polyester resin's density is 1.132 g/cm3, its viscosity at 25°C is 470 (cp), and its volatile content is 36.2%. Vasavibala Resins Pvt. Ltd., Chennai, was the supplier of polyester resin, catalyst, and accelerator. The below table 1 highlighted the material properties of paddy straw and polyester resin.

Table. 1. Standard Material Properties

Property	Paddy Straw Fibre	Polyester Resin
Density (g/cm^3)	0.45	1.1
Modulus of Elasticity (N/mm^2)	380.4	2.6
Thermal conductivity (W/mK)	0.128	0.22
Poisson's ratio	0.3	0.36

A. Alkali Treatment

The only reason raw paddy straw fibre isn't stronger than it might be is because of certain dirt and surface defects; otherwise, it may be used straight to make composite laminate. We need to apply the chemical treatment in order to increase the strength. There are several other chemical treatments available, including peroxide, calcium hydroxide, sodium hydroxide, and silane. NaOH is the most effective therapy for the other chemical treatment methods, according to the literature. In Figure 1, the fibres of paddy straw are treated with NaOH. pellets of NaOH that were gathered from stores. Paddy straw treatment involves a 5% NaOH concentration and a 24-hour soak period. The fibre surface becomes rougher and pores are created by the alkali treatment. The improved porosity and surface roughness help the reinforcement and polyester matrix adhere to one another and mechanically interlock better.

Fig. 1. Alkali Treated Fiber (Paddy)

III. COMPOSITE FABRICATION

A 300 x 300 x 3 mm semi-automated compression moulding machine was employed. There have been three weight percentage ratios used: 70:30, 60:40, and 50:50. The laminate was created with fibre that was orientated randomly. Polyester resin, along with the catalyst and accelerator, was blended in a ratio of 1:0.015:0.015 and by hand mixed for 2-3 minutes in order to avoid agglomeration. After arranging the fibres in the mould container in an arbitrary orientation, the mixed resin was poured over the fibres. 50°C and 30 bar of pressure were applied for 45 minutes. After 45 minutes, the fabricated laminate was placed at room temperature. In the other 60:40 and 50:50 ratios, same approach yielded the same outcomes. The applied pressure increases in tandem with the fibre %. Table 2 displays the results of fabricating and tabulating a set of six permutations of composite plates, where UT stands for untreated and ALT for alkali treated.

Table. 2. Compositions of composites

S. No	Specimen Name	Composition (wt %)	
		Resin	Fiber
1	UT-1	70	30
2	UT-2	60	40
3	UT-3	50	50
4	ALT-1	70	30
5	ALT-2	60	40
6	ALT-3	50	50

A. Experiment Test

Mechanical characteristics – As required by ASTM D638-08, D790-15, D256-10, D3846-08, and D hardness tests, specimens were made from the produced composite plates by cutting them to the appropriate ASTM dimensions. Using a universal testing machine (Tinus Olsen H10 KL) with a crosshead speed of 1.5 mm/min, three-point bending and tensile tests were performed. Izod employed a pendulum model impact test device with a 25-joule capacity. Five different samples were taken for each test, and the average outcome was noted. Figure 2 displays an image of the specimen used in the tensile test before and after.

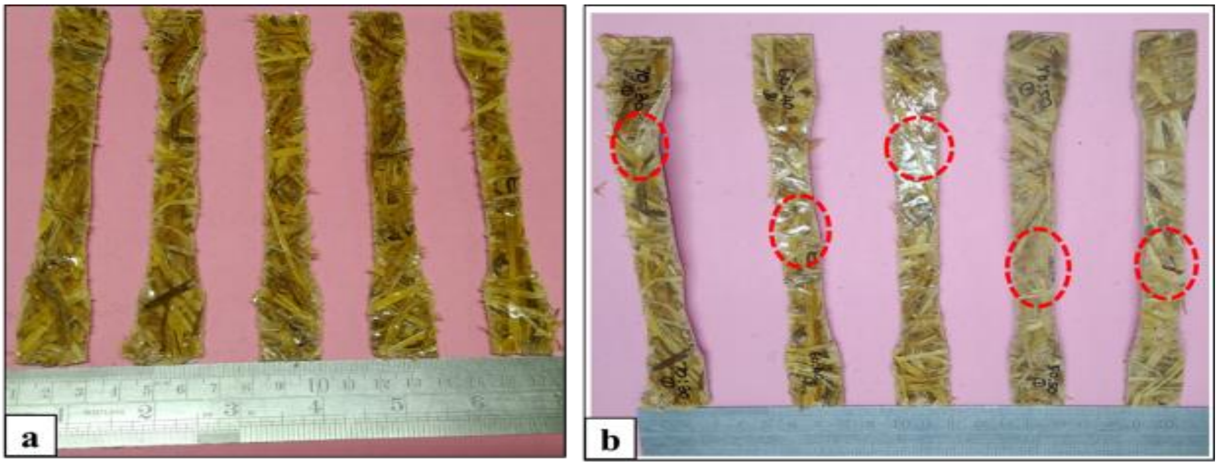

Fig. 2. Tensile Test Fractured Specimens A) Before B) After

Single fiber test – The capacity to obtain several pieces from a single specimen and the convenience of sample preparation are two important practical features of the single fibre fragmentation test. just one fibre testing Tensile testing equipment Zwick-Roell Z010, 10 KN; ASTM standard D 3822; preload: 0.1 N; test speed: 60 mm/min. The average force, tenacity, and strain values are noted after testing ten filaments.

X-Ray Diffraction – The samples were made using powder, and the X-ray diffraction data was gathered using a Rigaku Ultima3 X-ray equipment. The quantity of cellulose I and the crystallinity index were calculated based on the XRD data to access the performance of the treated and untreated fibre.

Fourier Transform Infrared Analysis – Among the most significant analytical methods used in fiber-reinforced polymers nowadays is infrared spectroscopy. The FTIR method is a wonderful tool to check the kind of bonds and the functional group scattering in composites by measuring molecular vibration. This investigation makes use of a Perkin Elmer RX I equipment. The FTIR spectra of the raw and treated fibres were confirmed using 32 scans at a resolution of 4 cm-1, ranging from a wave number of 4000 to 500 cm-1.

Thermogravimetric analysis – Investigating the thermal degradation behaviour of natural fiber-reinforced composites is required to determine their appropriateness for applications at higher temperatures. Thermogravimetric analysis was performed at 10°C/min, with a temperature range of 35°C to 600°C. At a mass flow rate of 20 millilitres per minute, N2 gas was continually pumped into the heating systems to maintain the inert atmosphere.

Surface topography – The most effective experiment to examine the morphology of the fiber surfaces of cracked composite materials is scanning electron microscopy (SEM), which should be used after testing. SEM Manufacturer / Model: Thermosceintific Apreo S. Finding the surface picture of the fibre after it has been treated and after breaking the broken specimens is the goal.

IV. RESULT AND DISCUSSION

Figure 3 displays the tensile strength data for various weight percentages of the paddy straw. The tensile strength of the 50-weight percent NaOH treated composite is 20 MPa, which is 0.75 and 0.85 times greater than that of the 70 percent ALT-1 and the 60 percent ALT-2. Composites treated with NaOH have a higher tensile strength than those that are not; this is seen in the comparison. As per the findings, the tensile strength increases as the proportion of weighted fiber increases due to the superior adhesive properties and interfacial bonding present in the reinforcement and matrix. The primary goal of this research is to employ less matrix and greater reinforcement material. The enhanced tensile properties of all NaOH-treated fiber-reinforced composites in comparison to their corresponding raw equivalent were ascribed to the treated fibres' increased single fibre strength and surface roughness.

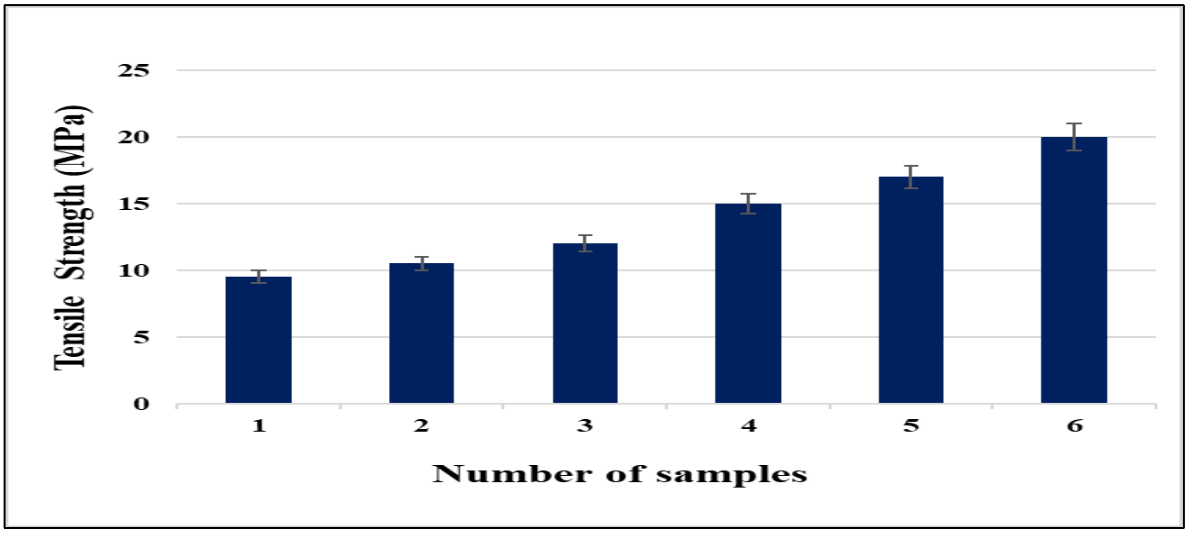

Fig. 3. Tensile Strength for Different wt%

Figure 4 displays the flexural strength results for various weight percentages of the paddy straw. In a similar vein, as the proportion of fibre weight increases, along with the flexural strength. The flexural strengths of ALT-1 and ALT-2 are 0.67 and 0.93 times lower, respectively, than the flexural strengths of the 50-weight percent NaOH treated composite (13.1 MPa). When flexural strength of NaOH-treated composites is compared to untreated weight (%) composites, the former values are greater. The findings show that poor adhesive properties between the reinforcement and matrix and uneven fiber dispersion cause the flexural strength to diminish. The absence of resin flow in the composite at lower fibre contents (30 wt%) is one of the reasons for the reduced flexural properties. The NaOH treatment filled the grafted molecules, reducing the pores and gaps on the fiber surface. It raised the surface roughness and enhanced the interfacial contact between the fiber and the matrix by eliminating contaminants such as hemicellulose, wax, oil, pectin, lignin, and pollutants from the fiber's surface.

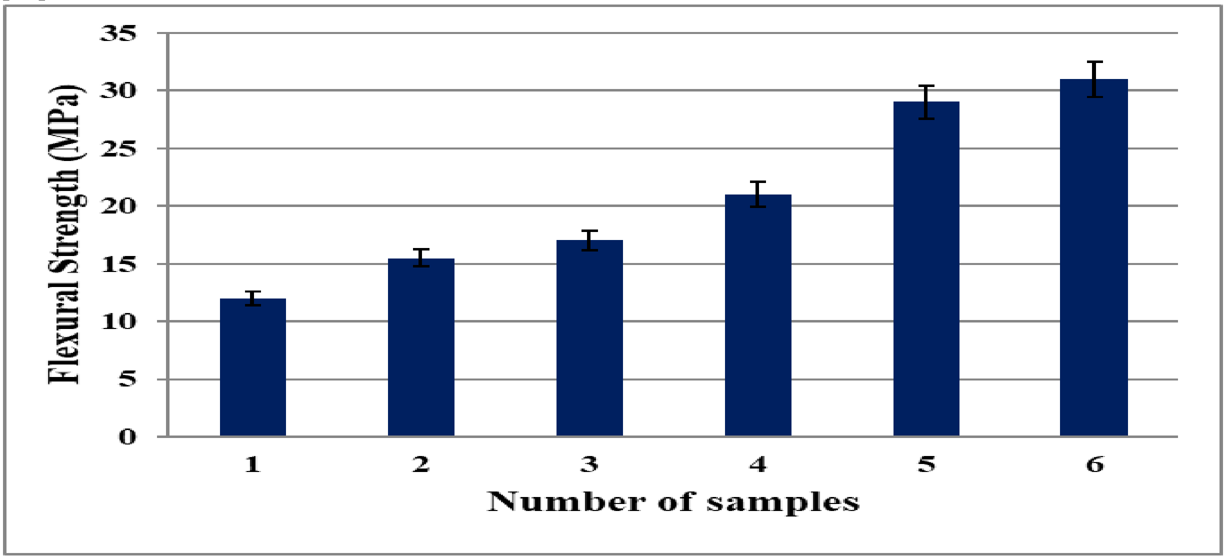

Fig. 4. Flexural Strength for Different Composite (paddy straw)

One important aspect of the material's engineering is the abrupt load action. In Figure 5, impact strength data for various weight percentages of the paddy straw are displayed. The impact strength increases with the addition of fiber weight percentage along to the matrix increases the stiffness and hardness of the composites and it can be exhibited good adhesive bonding between the reinforcement and matrix. The impact strength (62 KJ/m^2) of the 50-weight percent NaOH treated composite is 0.645 times and 0.548 times more than the flexural values of 40 KJ/m^2 and 34 KJ/m^2. to lessen the impact characteristics, which include holes, cavities, and poor interfacial bonding between the matrix and fibre.

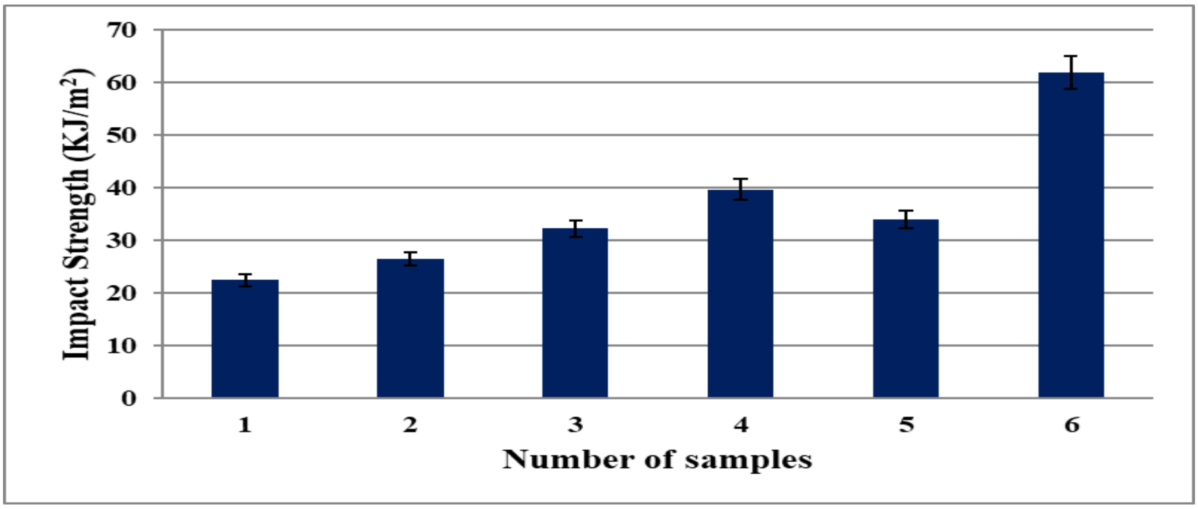

Fig. 5. Impact Energy for Paddy Straw Composites

Impact strength is calculated from the energy needed to decompose the sample. This energy is dependent on several factors, such as the toughness of the matrix, the fibre surface shape, fibre quality, and the kind of crystallinity present in the fibre and matrix. It is predicted that, in comparison to untreated fibre, there would be good stress transmission between the polyester matrix and the paddy straw reinforcement. The overall mechanical properties of fabricated tested composites are shown in Table 3 and comparative graph represents in figure 6.

Table. 3. Results of Mechanical Characteristics

Specimen	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (KJ/m^2)
1	9.5	12	22
2	10.5	15.5	26
3	12	17	32
4	15	21	40
5	17	29	34
6	20	31	62

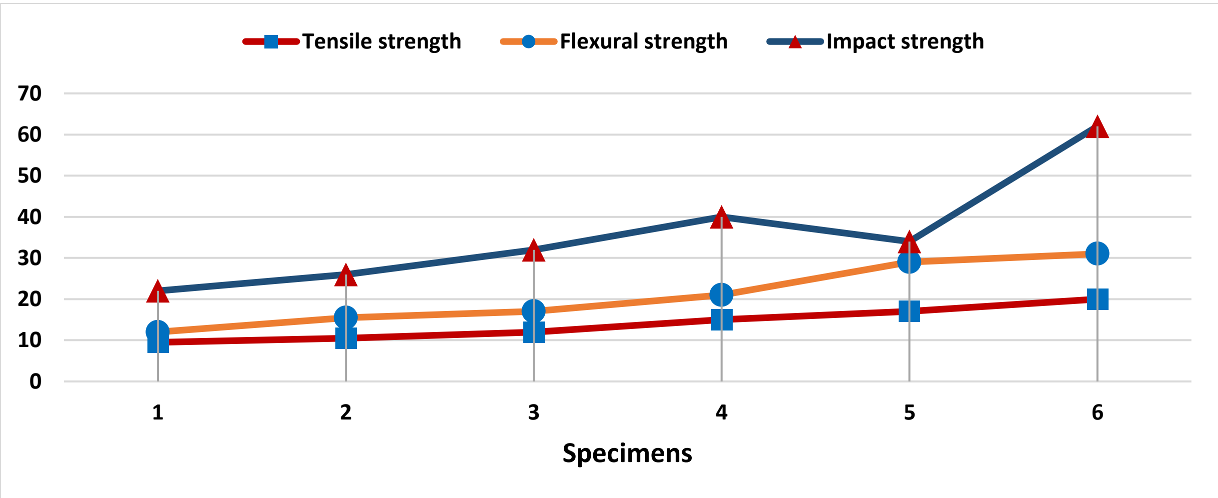

Fig. 6. Comparison Chart of Mechanical Properties

Figure 7 displays the single fibre test results for both raw and treated fibre. Ten individual fibres were tested, and Table 4 shows the average results. The tensile strength of treated and raw fibres is likewise about equal. For both raw and treated fibre, the obtained elongation values are 1.2% and 2.0%, respectively. The maximum permitted forces for treated and raw fibres, respectively, are found to be 83.748 N and 106.892 N. The fiber's surface area increased after the NaOH treatment, and some of the lignin and hemicelluloses were removed. A larger area of contact between the fibre and the matrix resulted from the hydroxyl groups on the cellulose fibres' increased ability to interact with the sodium hydroxide-coupling agent due to the increased number of possible reaction sites. Chemical degradation (which weakens the fibre and may somewhat reduce its single fibre strength) and changes in crystallinity (which alters the fiber's ability to withstand tensile forces and consequently reduces single fibre strength) result in a decrease in the single fibre tensile strength following surface treatment.

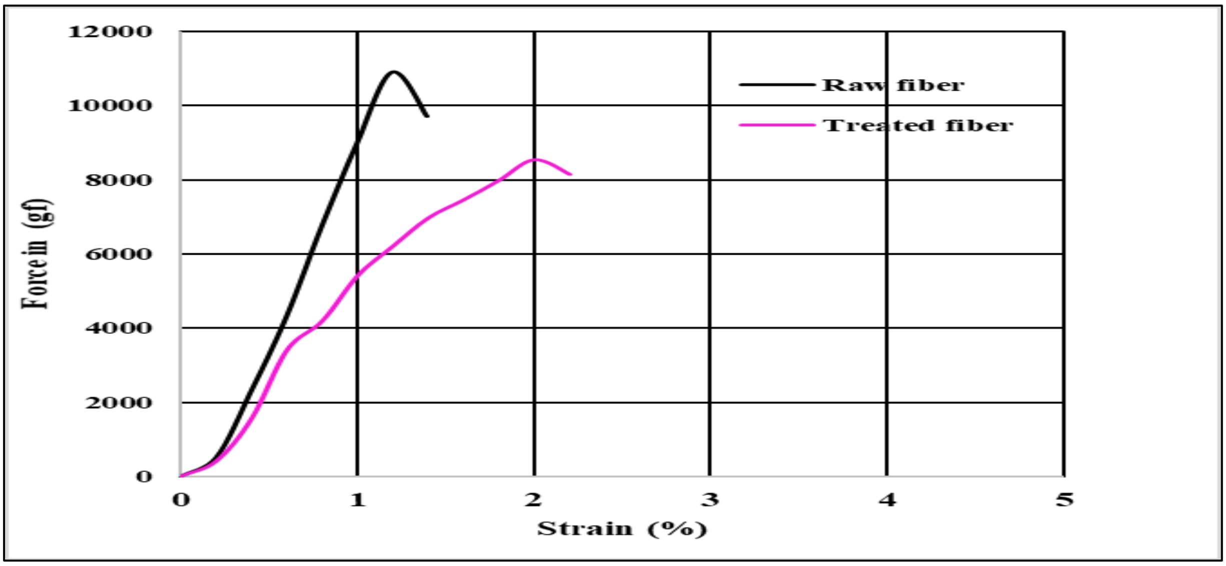

Fig. 7. Single Fiber Test – Raw and Treated Fiber

Table. 4. Fiber Statistics Report

Material	F_{max} (gf)	Tenacity (g/den)	dL at F_{max} (%)
Raw fiber	10900	1.14	1.2
Treated fiber	8540	1.10	2.0

Figure 8 displays the results of an X-ray diffraction examination of raw and processed paddy straw fibre. Alkali treatment modifies the fiber surface chemically by breaking down cellulose chains and increasing the presence of hydroxyl (OH) groups on the fiber surface. Improved interfacial adhesion results from the creation of additional active sites for chemical interaction with the polymer matrix. The diffractogram showed a single major peak that corresponded to the crystallographic planes. The crystallinity index was computed by comparing the areas between crystalline peaks and the amorphous curve. The graph revealed that the paddy straw fibres show two high peaks: 2θ= 16.28° at the (110) crystallographic plane and 2θ = 22.57° at the crystallographic plane of (200).

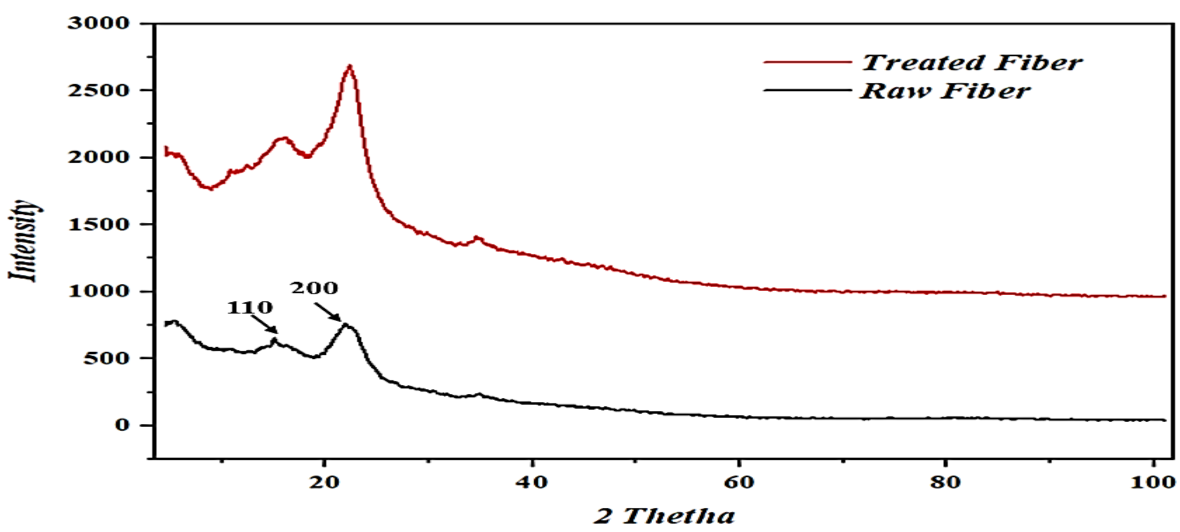

Fig. 8. X-ray diffraction Analysis of Paddy Straw Fiber

Fourier Transform Infrared (FTIR) can assist in identifying the functional groups present in the fiber, highlighting the chemical differences between the fiber constituents. Figure 9 displays the Fourier Transform Infrared spectra (FT-IR) analysis of raw and treated paddy straw fibre. The spectra were detected in the region of 4000 to 500 cm^{-1}. The extreme absorption peak was noted at 1028 cm^{-1}, which showed the presence of the (CO) and (OH) polysaccharides group present in the cellulose contents. 1240 cm^{-1} shows the CO stretching vibration of the acetyl group. The presence of wax contents (CC stretching) dispersed with the fiber was confirmed by the peaks that occurred at 2918 cm^{-1} and 2857 cm^{-1} existence of cellulose and hemicellulose in the paddy straw fiber. The stretching of the hemicellulose contents' C=O group was identified as the cause of the peak that emerged at 1612 cm^{-1}. The C=H group of the lignin contents is linked to the area between 1439 and 1252 cm^{-1}. In this phenomenon are an indication of the removal of hemicellulose, pectin, lignin from the paddy straw fibers during alkali treatment.

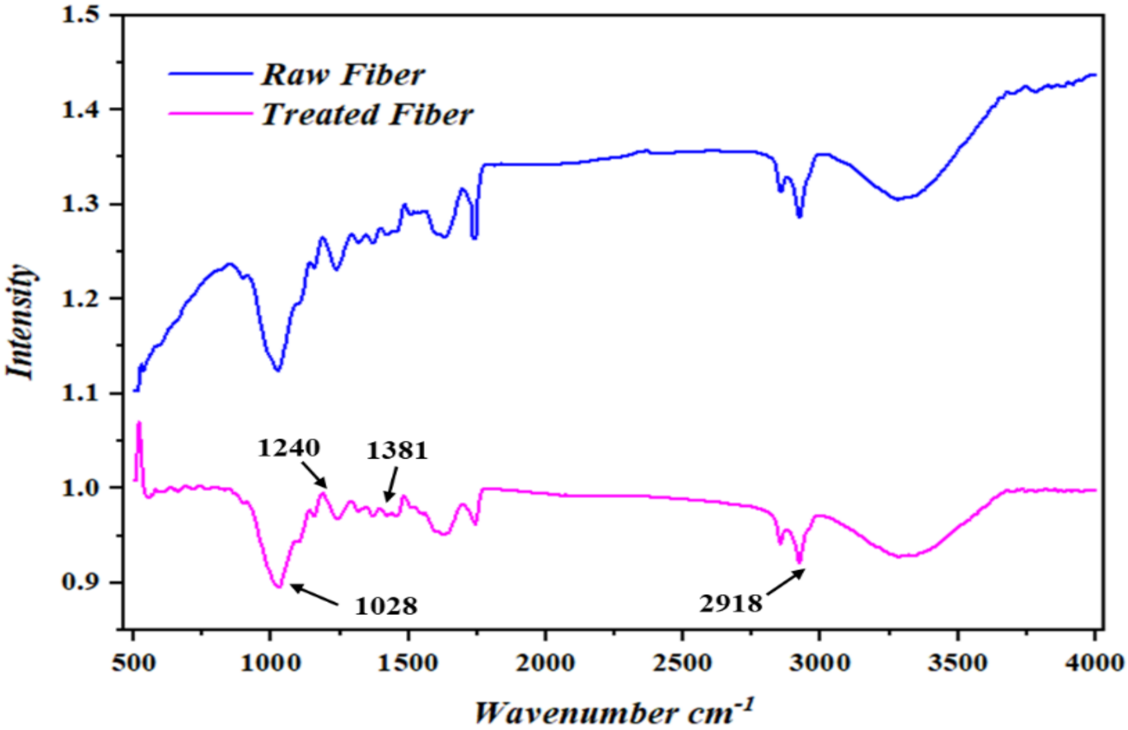

Fig. 9. FT-IR Analysis of Paddy Straw Fiber

Figures 10(a) and (b) display, respectively, the TGA examination of untreated and processed rice straw fibre. The constituent's hemicellulose, cellulose, lignin, wax, and other elements are typically involved in the thermal breakdown of a natural fibre at high temperatures. Three sections comprise the thermogram. Because the hemicelluloses were breaking down, the first weight loss area (also known as the first shoulder peak) happened between 205°C and 278°C. Region II is linked to the greatest reduction in weight and the thermal depolymerization of cellulose, lignin, and the residual hemicelluloses. The breakdown peak occurs in this region between 278°C and 346°C. Region III (the third phase of weight loss) occurs between 346°C and 700°C and is caused by further cellulose glucosidic chain breaking as well as non-living material components.

For the morphological examination, surface images were taken at different magnifications using a scanning electron microscope. Figure 11, Raw and treated paddy straw fibre examined using SEM. Raw paddy straw fibres have a greater concentration of bound hemicellulose and cellulose and some surface dirt. The fibres of treated paddy straw have a surface that is both rough and smooth. To ensure that the fibre and matrix material fuse flawlessly throughout the composite's production process, the cellulose and hemicellulose content of the alkali treatments is reduced.

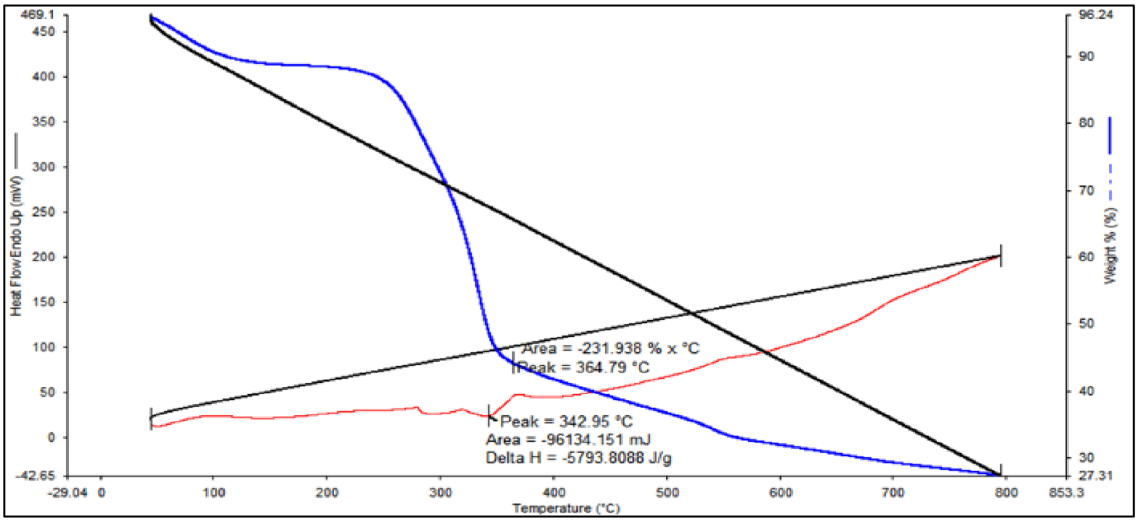

Fig. 10 (a). TGA Analysis of Raw Paddy Straw Fiber

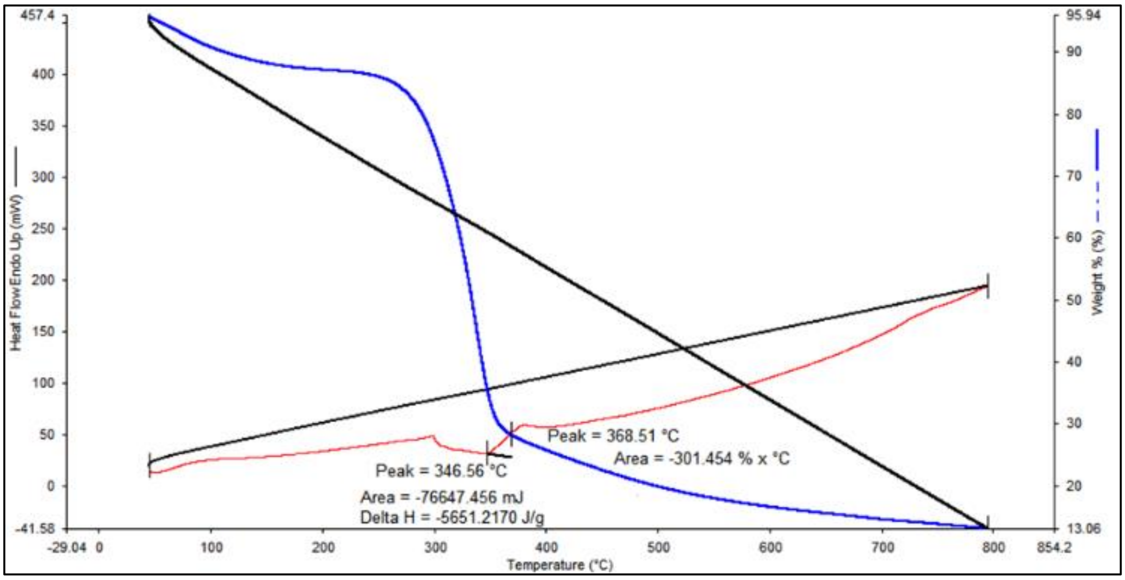

Fig. 10 (b). TGA Analysis of Treated Paddy Straw Fiber

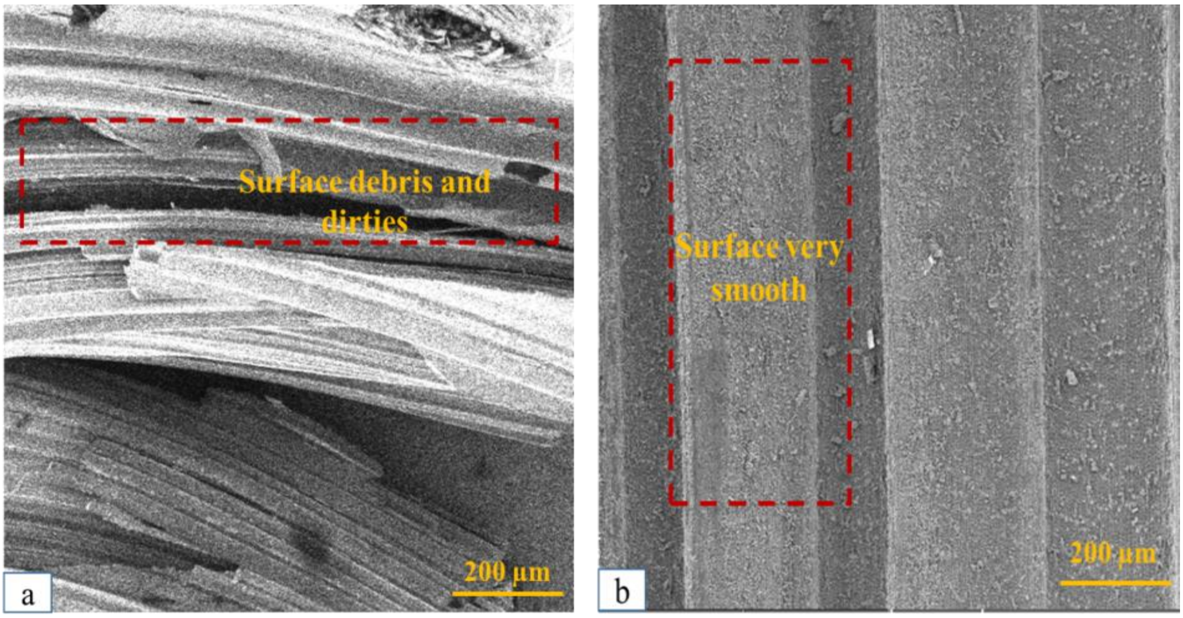

Fig. 11. SEM Micrograph of Raw and Treated Fiber Composites

V. CONCLUSION

This study examined the mechanical, morphological, and fibre characteristics. The following is a list of the noteworthy outcomes.

- Paddy straw fibre is gathered from farmland and undergoes an alkali treatment procedure to enhance its mechanical properties.
- The effectiveness of the raw and alkali-treated fiber was assessed using the XRD data. The chemical groups associated with the quantities of cellulose (O=H), hemicellulose (C=O), lignin (C=H), and wax (C≡C) were confirmed by FTIR study.
- The thermal stability of the paddy straw fiber was ascertained using TGA and DTG diagrams. It was found that cellulose degraded at 325 °C and hemicellulose at 234 °C.
- SEM data show that the fibres in paddy straw are semi-smooth, porous, and composed of cellulose, hemicellulose, and wax.
- Polyester composites were reinforced with randomly oriented paddy straw fibers using a semi-automated compression molding machine with various weight ratios.
- Tensile, flexural, and impact tests yielded total weight percentages of 20 MPa, 31 MPa, and 62 KJ/m2 for consecutive weight percent, respectively, when a 50:50 ratio was used. Certain flaws, including pull-out, voids, empty portions of the matrix, fibre breaking, and others, were seen in the micrograph of the cracked specimen.

According to the overall findings, paddy straw fibre is a material that is frequently used in non-structural applications such writing pads, door panels, partition boards, two-wheeler number plates, table tops, and others.

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