INVESTIGATION OF MECHANICAL PROPERTIES OF PALM SPROUT FIBER REINFORCED COMPOSITES

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Abstract: Nowadays natural fibers are gaining added importance as reinforcement in fiber reinforced composites because of ecological concern. Natural fibers are easily available, lightweight, can be easily extracted and biodegradable. The aim of this study is to find the chemical and mechanical properties of palm sprout fibers and mechanical properties of palm sprout fiber reinforced composites. In this work palm sprout fibers were extracted from palm sprout and treated with 5% sodium hydroxide (NaOH). Composite specimens were made using palm sprout fiber as reinforcement and epoxy resin as matrix for different ratios such as 30% fiber & 70% resin and for 40% fiber & 60% resin for both treated and untreated fibers. Chemical test, water absorption test, tensile test, FT-IR (Fourier Transform Infrared Spectroscopy) test and Scanning Electron Microscopy (SEM) were condu cted for palm sprout fibers. Tensile, flexural and impact tests were performed on composite specimens made by hand layup method. From the results it becomes clear that the composite specimen having treated palm sprout fibers as reinforcement in the ratio of 40% fiber (reinforcement) and 60% resin (matrix) shows better mechanical properties than untreated.

Keywords: *Palm sprouts fibers, hand layup method, chemical test, and mechanical properties.*

1. INTRODUCTION

Natural fibers are used as reinforcement in composites because they are decomposable, available at less cost and can be extracted easily. By studying their mechanical properties they can be used as substitute in industries according to their strength. Previously numerous research works were carried out to find the replacement of synthetic fibers by using natural fibers as reinforcement in composite laminas. Some research works involving natural fibers related to this study were discussed. Boopathi et al have proved that natural fibers could be used as reinforcement for making composite specimens and tensile force of 5% alkali treated borassus fruit fibers were higher than raw fibers. They showed that impurities present in the raw fibers were removed due to alkali treatment. FT-IR analysis and morphology studies of borassus fruit fibers confirmed the same [1]. Goulart et al evaluated the flexural properties of polypropylene reinforced palm fiber epoxy composites as per ASTM – D – 790 Standard. They found that addition of coupling agent in the composites improved significantly the flexible strength & modulus when compared to pure polymer [2]. Darshil et al had showed that low fiber content were prone to intra-yarn voids and high fiber content were prone to inter yarn voids due to change in resin flow dynamics with increasing fiber volume fraction [3]. Singha et al carried out FT-IR to find the bonds present in natural fibers. They had studied both raw and surface modified agave fiber reinforced with polystyrene matrix and found that 20% fiber content contributed for optimum mechanical properties [4]. Nuthong et al used ASTM-D 256 to find impact strength of flexible epoxy treated composites and it was higher than the untreated composite. They had also made known that poor interfacial bonding resulted in poor energy dissipation between natural fiber and matrix [5]. Yusriah et al conducted water absorption of betel nut husk fibers and concluded that they might be applied for light weight applications [6]. Sapuan et al studied the mechanical properties of sugar palm fiber reinforced with high impact poly styrene (HIPS) composites for different fiber loadings by weight and found tensile strength increased with increase in fiber loading [7]. Rokbi et al conducted chemical treatment on natural fibers with 1, 5 & 10% NaOH for 24 & 48 hours. They found that part of cementing compounds such as hemicellulose and lignin on the surface of fibers decreased due to alkali treatment and concluded that 5% NaOH treated composites had better tensile strength [8]. Suhairil et al found that 6% alkali (NaOH) treatment had improved the tensile properties of kneaf fibers when compared to untreated fibers [9]. Merlini et al found lumen and cell wall in the SEM image of banana fiber composites. They chemically modified the banana fibers in 10 % of sodium hydroxide solution for one hour and characterized through FT-IR, SEM, tensile and density measurements. They observed the modifications in the fiber chemical structure [10]. Dhanalakshmi et al proved that due to alkalization water absorption properties of areca fiber could be improved and mechanical properties of areca fiber composites could be increased through acetylation [11]. Beniniet al conducted tensile analysis as per ASTM-D 638 for sugarcane bagasse fiber composites. They found that cellulose is completely insoluble in water and chemical treatment removed residual lignin from fiber surface [12]. Fairuz et al used hand layup technique to make coir fiber reinforced epoxy composite, with resin to hardener ratio of 4:1 and found that tensile strength was decreasing when the fiber content was increased [13]. Bahruddin et al carried out water absorption test for palm based fly ash reinforced composites and it was noted a decrease in mechanical properties, especially tensile strength at higher fiber stuffing [14]. Vivek et al used epoxy resin as matrix for making jute fiber composites by hand layup technique for different fiber loadings and found that impact strength increased with increased fiber loading [15]. Ramesh et al used hand layup process for making glass fiber – sisal/jute reinforced epoxy composites and made the lamina for 5 mm. They conducted tensile and flexural test as per ASTM-D 638 and ASTM-D790 standards respectively at room temperature. The result indicated that incorporation of sisal fiber with GFRP exhibited superior properties then the jute fiber reinforced GFRP composites in tensile properties [16]. Mulinari et al studied the mechanical properties of coconut fiber reinforced polyester composites and found the removal of wax, pectin, and lignin and hemi cellulose after alkali treatment. They noticed increased adhesion between fibers and matrix due to alkalization [17]. Mileo et al studied the mechanical behavior of sugarcane straw cellulose composites and prepared composites for 5, 10, 15 & 20% by fiber weight. They conducted flexural test and found poor dispersion of fibers in the fracture region [18].

Palm sprout is available in plenty and a natural fiber is used as reinforcement in this study. Palm trees are growing everywhere and the palm sprout is obtained from palm trees. Palm sprout fibers can be easily extracted from palm sprout without utilizing any energy. Palm sprout fiber is renewable and also biodegradable. Hence this work aims to explore the potentials of palm sprout fibers and their suitability as reinforcement in place of synthetic fiber composites.

2. MATERIALS AND EXPERIMENTS

2.1 Extraction of fiber

Palm sprouts fibers were obtained from palm trees and submerged in water for two to three days. Palm sprout is mainly made of starch which absorbs water and becomes loosen. Palm sprouts were taken out of the water and softly rammed for removing starch. The starch sticking to the fiber is washed many times in water until they were removed. Then the fibers were extracted and dried for removal of moisture. Palm sprout and raw palm sprout fibers are shown in figure 2.1.

Figure 1: Palm sprout and raw palm sprout fiber

2.2 Alkali treatment of fibers

The dried palm sprout fibers were treated with 5% NaOH solution for about half an hour at room temperature. Then the fibers were washed with deionized water to remove the NaOH sticking on its surface. The fibers were then neutralized with 2.5% HCL solution at room temperature for 24 hours [1]. Alkali treatment is done to remove the impurities sticking to the fiber and make the fiber surface smoother.

2.3 Chemical properties

Wax content, moisture content, cellulose content and lignin content were found for raw and 5% alkali treated fibers. The purpose of this test is to find the different chemical compounds of treated and untreated fibers.

2.4 Fourier Transform Infrared Spectroscopy test

It is a non-destructive technique. An infra-red spectrum indicates a finger print of a sample with absorption peaks which corresponds to the frequencies of vibration between the bonds of the atoms making up the material. FT-IR was conducted to find the different bonds and chemical compounds present in the raw and alkali treated fibers. The test was performed using the thermo scientific NICOLET IS10 spectrometer at room temperature.

2.5 Scanning Electron Microscopy (SEM)

SEM is an excellent technique for examining the surface morphology of fibers. SEM image was taken to study the difference in surface morphologies of raw and alkali treated fibers. Images with different magnifications of raw and alkali treated fibers were taken and the micro structure of the fibers was studied. SEM images were taken by machine model JEOL-JSM-6390.

2.6 Palm Sprout Fiber Tensile Test

Fifty samples of untreated and alkali treated palm sprout fibers tested for tensile strength and the maximum, minimum and mean values were noted. Tensile properties of palm sprout fiber were determined. The test is performed by using machine INSTRON 5500 R-60211.

2.7 Hand layup technique

Palm sprout fibers were equally cut for 5 mm. In this method epoxy resin and hardener was thoroughly mixed in the ratio of 4:1. Required volume of fibers (30% & 40%) were separately added to the mixture of resin and mixed continuously to remove air gaps. Then the mixture was spread in the mould and a compression load is applied for 24 hours. The thickness of the plate was ensured to be 5 mm by giving the load uniformly. The composite specimens were removed from the mould after the curing time of 24 hours [13].

2.8 Tensile test of composite specimen

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. Five specimens of raw and alkali treated fiber reinforced composites were tested the mean values were taken. Tensile test was performed according to ASTM-D 638 [13]. Tensile test specimens were tested in Electronic tonometer – Model PC 2000 operated with a 20KN load cell with digital load controller and extension microprocessor based elongation measurement set up. The cross head speed was 5 mm/min and the gauge length maintained was 50 mm.

2.9 Flexural test

Flexural strength is the ability of a material to resist deformation under bending load. Flexural test was performed by three points bending method according to ASTM-D 790 [2&18]. The size of the specimen was 127 mm × 12.7 mm × 5 mm. The Kalpak universal testing machine KIC-2-0200-C with the capacity of 20 KN was used for conducting the flexural test at 28 °C and at relative humidity of 50 ± 2%.The cross head speed was 2 mm/min.

2.10 Impact Test

Impact properties of untreated and 5% alkali treated palm sprout fiber reinforced composites specimens were tested using an IZOD digital impact tester according to ASTM D 256 standard. The specimen was tested to determine the impact resistance and impact strength of composites at room temperature. The test specimen was supported by a vertical cantilever beam and was broken by a single swing of a pendulum. The size of the specimen is *64 x 13 x 5* mm^3 and the specimens were notched. The Izod digital impact tester, *Frank–53568* was employed for conducting the impact test at room temperature

2.11 Types of composite specimens:
Untreated and 5% alkali treated palm sprout fiber reinforced epoxy composite was made as per the types mentioned in table 2.1.

Table 1: Different compositions of composite Specimens

Type	Notation	% of Fiber	% on Resin
Untreated	UT1	30	70
	UT2	40	60
Treated	T1	30	70
	T2	40	60

3 RESULTS AND DISCUSSION

3.1 Chemical properties of palm sprout fibers

The different chemical components such as cellulose, lignin, wax, ash contents were tabulated for untreated and 5% alkali treated palm sprout fibers. The moisture and density values were also given in the table 3.1.

Table 2: Chemical properties of palm sprout fibers

Fiber category	Cellulose Content %	Lingnin Content %	Wax content %	Ash Content	Moisture Content	Density (g/cc)
Untreated Palm	62.51	11.28	Fiber Category	2.32	11.96	1.2302
Treated Palm Sprout Fiber	66.25	8.92	0.39	5.94	12.52	1.2357

The cellulose content, wax content & ash contents were found increased after alkali treatment and lignin content was found decreased. Cellulose content was increased from 62.51% to 66.25% because of the alkali treatment of fiber as they are hydroxyl groups. Lignin content in treated palm sprout fibers was decreased from 11.28% to 8.92% since they are partly soluble in NaOH. Wax content was increased from 0.24 to 0.39% and ash content was increased from 2.32% to 5.94%. Moisture content was increased from 11.96% to 12.52% due to the moisture absorption during alkali treatment of fibers [1].

3.3 Surface Morphology of Palm Sprout Fibers:

Presence of non-cellulosic elements and hemi-cellulose were noticed on the untreated fiber surface (Fig 3.1 a). Removal of wax, lignin and hemicelluloses from fiber surface was noticed on the treated fiber. Hence the fiber surface becomes rough [2]. The removal of these impurities explored the pores present on the fiber surface (Figure 3.1 b). Due to this the contact area of the fiber gets increased while reinforcing in composites.

3.4 Fourier Transform Infra-Red Spectroscopy Results

FT-IR analysis was made for raw and 5% alkali treated fibers and chemical peaks were identified. Figure 3.2 shows the FT-IR spectrum of the raw fiber.

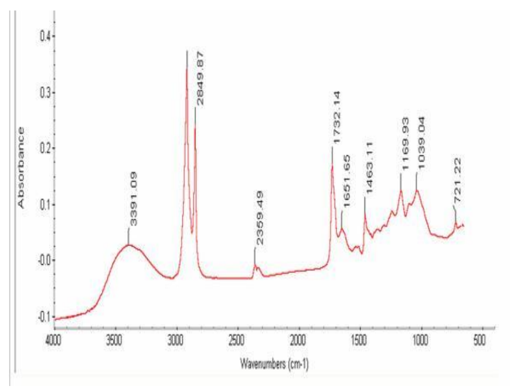

Figure 1: FT-IR Spectrum of Untreated palm sprout Fiber

The peak at 1039.04cm^{-1} is assigned to Si-O-Cellulose bond and this peak indicates the presence of sulfur and lignin. The bond in the peak 1651.65cm^{-1} indicates C=O stretch. The bond around 2359.49cm^{-1} was assigned to carboxylic acids with O-H stretching. The peak at 3391.09 cm^{-1} indicates existence of hydrogen bond in the fiber microstructure [1].

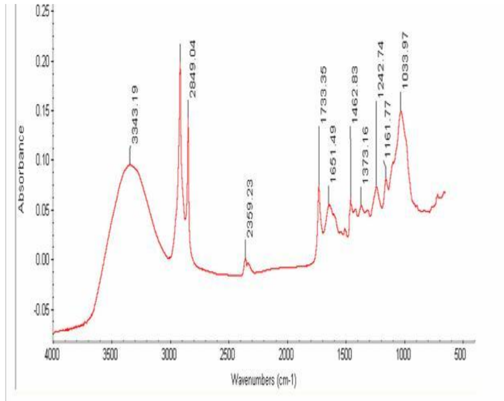

Figure 2: FT-IR Spectrum of Treated palm sprout Fiber

The FT-IR spectrum of the 5% alkali treated fibers is shown in figure 3.3. It was noted that the peak at $1033.97cm^{-1}$ is reduced from $1039.04cm^{-1}$ because of removal of lignin content during alkalization. The peak at $1651.419cm^{-1}$ indicated the increase of cellulosic content, which improves fiber strength. The peak at $2359.23cm^{-1}$ was assigned to carboxylic acids with O-H stretching. The peak at $3343.19cm^{-1}$ was found increased and correlated to the strengthening of hydrogen bonds [17].

3.5 Tensile properties of Palm Sprout Fibers

The table 3.4 shows the tensile test result of untreated and 5% alkali treated palm sprout fibers.

Table 3: Palm Sprout Fiber Tensile Test Result

S.No	Maximum Load (gf)	Tensile Strain at maximum load
Untreated	589.56	4.83
Treated	631.94	7.33

That of the untreated fibers tensile strength, similarly the tensile strain of treated fibers was found higher than that of the untreated fibers. Hence it can be confirmed that 5 % alkali treatment improved the tensile properties of palm sprout fibers.

4. MECHANICAL PROPERTIES OF PALM SPROUT FIBER REINFORCED COMPOSITE SPECIMENS

4.1 Tensile Test Results

Tensile strength of type T2 composites was found improved when compared to other categories. This is due to improvement of bonding between fiber & reinforcement by 5% alkali treatment. It is also noticed that more fiber content i.e, 40% palm sprout fiber as reinforcement lead to enhanced tensile strength (1362.71 N).

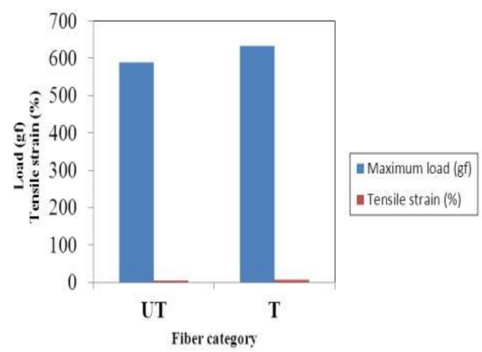

Figure 3: Palm Sprout Fiber Tensile Test Result

The results revealed that treated palm sprout fibers are having more tensile strength than untreated palm sprout composites. Because alkali treatment removes the impurities from fiber surface and make the fiber surface rough. The maximum load taken by treated palm sprout fibers was 631.94 gf which was higher

The table 4.1 shows the tensile test values of composite specimens for various types.

4.2 Impact Test Results:

The table 4.2 shows the impact test values of composite specimens for various categories. Impact strength of treated composites of type T2 was found as 2.15 J.

Table 4: Tensile test results of composite specimen

Type	Type of composite	Peak Load (N)	UTS (N/mm)
Untreated	UTI	573.94	6.30
	UT2	858.95	9.43
Treated	T1	1198.41	13.16
	T2	1362.71	14.98

Table 5: Impact test results of composite specimens

Type	Type of Composite	Impact Strength
Untreated	UT1	1.25
	UT2	1.75
Treated	T1	1.70
	T2	2.15

Then impact strength of remaining three categories was noticed lesser when compared to type T2. This is because alkali treatment improved the bonding between fiber & reinforcement.

4.3 Flexural Test Results

The table 4.3 shows the flexural test results of composite specimens for various categories.

Table 6: Flexural test results of composite specimen

Type	Type of Composite	Peak Load (N)
Untreated	UT1	80.82
	UT2	120.63
Treated	T1	134.99
	T2	142.1

Flexural strength of type T2 composites was found as 142.1 J which is superior to that of other types. This is because 5% alkali treatment leads to the removal of impurities from the fiber surface and hence the fiber surface becomes rough and explores the pores. This lead to more penetration of matrix inside the fibers and hence the bonding is more strong.

5. Conclusion

The chemical and mechanical properties of untreated and 5% alkali treated palm sprout fibers and mechanical properties of palm sprout fiber reinforced epoxy composite specimens were investigated and the following conclusions were arrived at:

- 5% alkali treatment improved the tensile strength of the palm sprout fiber.
- The chemical test of palm sprout fibers conformed the increasing cellulose content of the fiber and the removal of impurities which increases the fiber strength.
- FT-IR analysis revealed the removal of impurities from the fiber surface and strengthening of hydrogen bonds of fibers. The scanning electron microscopy also ensured the same.
- Tensile, impact and flexural properties of type T2 (40% fiber content) was noticed higher than other types of composites. Better fiber matrix adhesion characteristics lead to this outcome.
- It is concluded that 5% alkali treated palm sprout fibers with 40% fiber content in the composites showed better mechanical properties. Hence this combination could be applied for low load bearing and structural applications.

REFERENCES

[1] L. Boopathi , P.S. Sampath, K. Mylsamy: "Investigation of physical, chemical and mechanical properties of rawand alkali treated Borassus fruit fiber", Composites Part-B 43 (2012) 3044-3052

[2] Goulart S.A.S and Oliveira T.A: "Mechanical Behaviour of Polypropylene Reinforced Palm Fibers Composites", Procedia Engineering 10 (2011) 2034–2039

[3] Darshil U. Shah and Peter J. Schubel : "Determining the minimum, critical and maximum fibre content for twisted yarn reinforced plant fibre composites", Composites Science and Technology 72 (2012) 1909–1917.

[4] A.S. SinghaandRaj K. Rana : "Natural fiber reinforced polystyrene composites: Effect of fiber loading, fiber dimensions and surface modification on mechanical properties", Materials and Design 41 (2012) 289–297.

[5] Wiphawee Nuthong and Putinun Uawongsuwan : "Impact Property of Flexible Epoxy Treated Natural Fiber Reinforced PLA Composites", Energy Procedia 34 (2013) 839 – 847.

[6] L. Yusriah and S.M. Sapuan : "Exploring the Potential of Betel Nut Husk Fiber as Reinforcement in Polymer Composites: Effect of Fiber Maturity", Procedia Chemistry 4 (2012) 87 – 94.

[7] S.M. Sapuan and D. Bachtiar : "Mechanical Properties of Sugar Palm Fibre Reinforced High Impact Polystyrene Composites", Procedia Chemistry 4 (2012) 101 – 106.

[8] Mansour Rokbi and HocineOsmani : "Effect of Chemical treatmenton Flexure Properties of Natural Fiber-reinforced Polyester Composite", Procedia Engineering 10 (2011) 2092–2097.

[9] Mohd Suhairil Meon and MuhamadFauzi Othman : "Improving tensile properties of kenaf fibers treated with sodium hydroxide", Procedia Engineering 41 (2012) 1587 – 1592

[10] Claudia Merlini and ValdirSoldi : "Influence of fiber surface treatment and length on physico-chemical properties of short random banana fiber-reinforced castor oilpolyurethane composites", Polymer Testing 30 (2011) 833–840.

[11] Dhanalakshmi: "Effect of chemical treatment on water absorption of areca fiber" Journal of Applied Sciences Research, 8 (2011): 5298-5305, 2012.

[12] [12] K. C. C. C. Benini, H. J. C. Voorwald, M. O. H. Cioffi:"Mechanical properties of HIPS/sugarcane bagasse fiber composites after accelerated weathering",Proceedia Engineering 10 (2011) 3246-3251.

[13] FairuzI. Romli, Ahmad Nizam Alias, AzminShakrineMohdRafie,DayangLailaAbang Abdul Majidd: "Factorial Study on the Tensile Strength of a Coir Fiber-Reinforced Epoxy Composite", AASRI Proceedia 3(2012) 242-247.

[14] [14] Bahruddinand A. Ahmad : "Morphology and Mechanical Properties of Palm Based Fly Ash Reinforced Dynamically Vulcanized Natural Rubber/Polypropylene Blends", Procedia Chemistry 4(2012) 146 – 153.

[15] Vivek Mishra, Sandhyarani Biswas: "Physical and Mechanical Properties of Bi-directional Jute Fiber epoxy Composites", Proceedia Engineering 51 (2013) 561-566.

[16] M.Ramesh, K.Palanikumar, K.Hemachandra Reddy: "Comparative Evaluation on Properties of Hybrid Glass Fiber- Sisal/Jute Reinforced Epoxy Composites", Proceedia Engineering 51 (2013) 745-750.

[17] D.R.Mulinari, Baptista, Souza, Voorwald: "Mechanical properties of coconut Fibers reinforced polyester composites",Proceedia Engineering 10(2011) 2074-2079.

[18] Mileo, P.C and Mulinari, D.R : "Mechanical Behaviour of Polyurethane from Castor oil Reinforced Sugarcane Straw Cellulose Composites", Procardia Engineering 10 (2011) 2068–2073.