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Experimental Investigation and Surface Morphology Study on Areca Fiber Composite Material

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Abstract

Composites manufactured from areca fibers had their characteristics assessed in recent research. Shape and size were determined by cutting the stem. It takes six months to dry the fibers once they are taken from the tree stem. Because pectin, cellulose, hemicellulose, and lignin make up the bulk of it. It has great regeneration capacity and is a resource material made of wood fibers. The untreated and chemically treated fibers are obtained by processing them with an alkali. One method of preparing composite laminates is the vacuum bagging process, which involves pressurization procedures to eliminate air gaps. The areca fiber's tensile strength both before and after the alkalization process is determined by conducting specimen mechanical property tensile strength tests in accordance with ASTM D3379. Thus, it will show the specimens' responses to tension pressures on natural fiber composites. The behaviour of areca fibers is studied using scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy (FTIR). FTIR spectrum investigations have shown that the cellulose recovered from areca fibers does not include any hemicellulose, lignin, or wax, and morphological examinations have shown that the fibers have been separated and that the deposits have been removed.

Keywords: Areca fiber, NaOH solution, SEM analysis, FTIR, alkalization process, tensile strength

INTRODUCTION

Almost every day since human civilizations began, composites have been used for practical purposes. Due to their numerous advantages, composite materials are currently the material of choice for engineers. They are extensively used in building structures that are associated with aeronautical and maritime engineering. A wide variety of sizes and forms are available for composites. Some are found in nature in both plants and animals; for example, wood has both strong cellulose fibers and the more fragile lignin that covers them. Collagen, a protein, and hydroxyapatite, a hard and brittle material, are the building blocks of bone, another composite

Areca catechu cultivates predominantly in the tropical Pacific, Eastern Africa and Asia, especially Malaysia, the Philippines, India and Sri Lanka. Areca catechu trees are abundantly grown in India and Sri Lanka where the betel nut is served with wrapping betel leaves with limestone paste. The areca tree grows straight up reaching tallness of 10–20 m. Its stem is traditional, solitary and slim with a circumference of 10–15 cm with circinate coeneal scars from fallen leaf sheaths or fronds. Abaca, Alfa, Areca, Flax, Jute, oil palm, sisal, and kenaf are examples ofhigh-strength natural fibers that are placed in a polymer matrix to form natural fiber polymer composites. The structure of thermoplastic matrix materials comprises of 1D, 2D or 3D dimensional molecules therefore these polymers

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have a propensity to make softer at a raised heat range and roll back its qualities throughout cooling. In contrast, thermosets are polymers that cure through a combination of heat, pressure, and light irradiation, they are highly cross-linked. Its structure, thermoset polymers have desirable qualities including modulus, strength, and a high degree of flexibility, which allows for the customization of final attributes.

The fruit, fronds, and stem leaves of the areca plant are the principal sources of areca fiber. In particular, with non-reversible polymers, the world is today presented with the problem of creating new and improved technologies and techniques to eliminate or make use of solid waste. Linta, pectin, cellulose, and other related elements make up natural fiber. The presence of these components affords natural fiber its unique features and attributes, including a high moisture percentage that impacts the bonding between the fibers and the matrix. By adding micro silica as a constituent and a chemical treatment technique adding NAOH solution to the fibers have been created and investigated by assessing FTIR & mechanical property and SEM analysis in an effort to address this issue by fulfilling the needed characteristics by reaching. Here, few different constituents which are presented in the natural fibers are listed in below Table 1.

Table 1. Constituents of Different Natural Fibers.

S.no	Fiber	Cellulose%	Hemi-cellulose%	Lignin%	Pectin%	Wax%
1.	Abaca	56-69	21-25	7-12	0.8	3
2.	Alfa	45.4	38.5	14.9	-	2
3.	Areca	57.35- 58.21	13- 15.42	23- 24	-	0.12
4.	Flax	62- 72.5	14.5- 20.6	2.5	0.9	0.22
5.	Jute	59- 71.5	12- 20	9- 13	0.2	0.5
6.	Kenaf	53.5	21- 33	17- 21.5	0	-
7.	Sisal	60-73	11.5- 14	8-11	1.2	-

In addition, synthetic composites exist. The tool and the wet laid-up laminate are covered with a plastic sheet to complete the vacuum bagging operation. By sucking the air out of the bag using a vacuum pump, may apply pressure on the laminate up to one atmosphere and solidify it. Polymers such as lignin, cellulose, and hemicelluloses, together with a handful of extractives, make up natural plant fibers. One component that helps keep plant cells physically stable is hydrophilic cellulose, which is the primary component of cell walls.

One way to get an infrared spectrum depending on the sample's absorption or transmittance is via Fourier transform infrared spectroscopy (FTIR). Its non-destructive measuring and structural analysis capabilities make it a popular choice. The Fourier transform infrared spectroscopy (FTIR) is a helpful diagnostic technique for clinical chemists since it quickly, easily, and accurately identifies chemical bonds and functional groups. Because Areca materials have very particular bands in the spectrum area due to their molecular structure, studying biochemical makeup and studying their nature assists with diagnosis. Spectroscopic methods rely on the wavelength of absorbed light and the manner in which different light frequencies interact with materials through emission or absorption within the electromagnetic spectrum; they are a simple, accurate, and useful diagnostic tool in clinical chemistry for differentiating between different types of chemical bonds and functional groups. To see and understand the areca substance's properties, one might look into spectroscopic techniques for assessing the biological makeup of materials. Their chemical make-up allows them to exhibit highly targeted spectral bands, which aids in process diagnostics. Maximum research arears

LITERATURE REVIEW

Investigating the relationship between the amounts of time spent alkalizing the lignocellulose and the tensile strength of individual fibers in areca leaf sheath Adilah Azmi Sarah [1]. The quality of the cellulose fibers was better understood when researchers compared the effects of acid and alkali

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treatments on Calotropis procera. An amount of NaOH (0.5N) was applied to about 6% of the cellulose fibers in C. proceragave. A 26% improvement in cellulose extraction efficiency was observed after treating fibers with a 10:1 (v/v) mixture of concentrated nitric acid and 80% acetic acid. The cellulose content % was determined using acid detergent fiber methods and infrared spectroscopy. The cellulose content of acid-treated fibers was 85 percent higher than that of alkali-treated fibers. by Raghu Patel G [2]. Determine if vacuum bagging is the most desirable way to get composite material. Advantages and disadvantages are present. Take the technique's labor-intensive and time-consuming nature as an example. The potential for its usage in the production of massive items, like as wind turbine blades, is an advantage. The authors are Siddharth Garg and colleagues. The third. Laminating the hybrid composites utilizing the hand lay-up procedure included employing areca sheath fibers, jute fibers, and glass textiles reinforced in the epoxy matrix. It has been tested using a lightweight application based on the findings of the study. Composites S Jothibasu [3] demonstrated minimal fiber pullout and strong fiber bonding in scanning electron microscopy experiments [4]. after determining the mechanical and wear properties, the areca fiber composites were compressed with fly ash, basalt powder, and WC. The mechanical and wear properties of fly ash, basalt, and WC filler powders were enhanced when combined with areca fiber Miniappan, P. K., [5]. Numerous industries make use of natural fibers, including construction, landscaping, cosmetics, pulp and paper, and the food industry. Additionally, they provide a wealth of raw materials for insulating buildings. Various techniques, features, and qualities of palm fiber manufacturing were discussed. By enhancing the contact between the fiber and the matrix component, composite materials may benefit from chemically reinforcing the surface of the fiber. Hi there, Suresh! This work is by Thirupathi [6]. In comparison to the individual materials, the composite's material qualities are superior. There are two common approaches to creating composites: the manual lay-up technique and the vacuum bag method, with the latter serving as an upgrade to the former. The group headed by Syarif Hidayat began [7]. The thermogravimetric study looked at the thermal stability of areca fruit bunches after they were treated with an alkali. Finally, alkali treatment of the areca fruit husk fibers was shown to be the most successful method for eliminating hemicellulose and lignin. Then, after processing, these fibers may be used in a variety of composite preparation methods Ravikumar [8]. The research shows that vacuum bagging outperforms hand lay-up when it comes to making composites. When it comes to making composites from liquid resin, however, the vacuum-assisted resin infusion process is the superior choice. The compressive and shear properties of the composite with a v-notch Kosim Abdurohman& colleagues [9]. The research found that a good thickness for optimizing skin depth could be determined. There are a number of uses for EMI SE composites, and our calculations show that five layers is the ideal thickness for these materials [10]. Malleable and pliable composites were used to light up an LED lamp after they had been shaped into complex shapes. The findings showed that the product qualities were influenced by the number of fiber layers, which in turn impacted the composites' thickness. The resin on fiber impregnation process was most impacted by vacuum pressure, with optimal product performance seen at 1 bar. Xianwen Dong and colleagues [11]. After conducting a tensile test on composites with different sheath fiber angle orientations, it was discovered that the composite with the orientation of 90°-90°-90° had the highest strength. Dinakaran [12]. To improve the bond between the fiber and matrix, the research found that natural fibers were treated with an alkaline solution. We looked at the epoxy hybrid composites' broken surface morphology using scanning electron microscopy (SEM). To examine the composites' thermal properties, Differential Scanning Calorimetric (DSC) and Thermogravimetric Analyzer (TGA) were used. Ranjan Swain, Priyadarshi Tapas, and colleagues [13]. Researchers are focusing more on affordable synthetic fibers, but found some more naturally reversible polymers derived from plants or agricultural waste that prevent the development of harmful substances after usage. This work is by R.B. Ashok and colleagues. Cited as [14]. Damage inspection of epoxy hybrid composites reinforced with carbon and ramie fibers shows less microscopic fractures, a sign of the material's ductility. Shukur Abu Hassan [15]. This study examined carbon/ramie fiber reinforced epoxy hybrid polymer composites for a variety of stacking sequences and ramie fiber orientations, testing their indentation resistance and damage assessment capabilities. The force-displacement curve of carbon/ramie fiber reinforced epoxy hybrid polymer composites shows many indentation force peaks, suggesting that the fibers were broken. Nahia Abu Hassan and colleagues [16]. In order to identify the changes, morphological analyses compared the surface topography of changed and unmodified areca fibers. Hence, synthetic polymer composites containing natural areca fibers would unquestionably benefit from surface modification of the fibers by alkali treatment, since this would enhance the fibers' adhesion to the polymeric resin. [17]. In his research the samples are prepared by adhering to certain procedures. To prevent polymer from adhering to the mould surface, a release antiadhesive agent is applied first. The product's surface is then made smooth by applying a thin plastic sheet to the top and bottom of the mould plate. Cut into the necessary forms, the woven reinforcing layers are laid out on the mold's surface laminates are prepared by hand layup process by Rajesh [18].

Recently many research works are doing on natural fibers. In that areca fibers are maximum research are doing on areca leafs and nuts, less research has done on stem of areca fibers here considering areca steam is taken in to consideration and more fibers can be extracted and most of the research work is done by using hand layup process to prepare composite materials. Here by using vacuum bagging process where wastage will be less and maximum blow holes, and porosity will be less as compare with hand layup process

Experimental Preparation for Laminate by Using Vacuum Bagging Process

In this experimental study, areca fiber, Araldite CY 205 epoxy resin, and a hardener. The percentage of ultra-light micro silica in the epoxy resin ranged from 5% to 20% by weight. Mixing micro silica with pre-calculated epoxy resin is the first step. After that, for about half an hour, the mixture was stirred gently and thoroughly using a portable electric stirrer. The composite specimens were made using six layers of areca fiber that was weaved in both directions. In order to arrange the layer to get the desired form when using the vacuum bagging process to make components, a mould is often necessary. Use of chemlease 7891 EZ as a mould cover and release agent is being investigated in this study.

Experimental Methodology

Figure 1 describes line diagram, Experimental setup for vacuum bagging process and alkali-treated specimens and untreated alkali specimens. By applying pressure to the laminate after it has been laid-up, this vacuum bagging technique improves its consolidation, and it is basically an extension of the wet lay-up process. The process consists of covering the wet laid-up laminate with a plastic sheet and then fastening it to the tool. To consolidate the laminate, the air beneath the bag is removed using a vacuum pump, which allows up to one atmosphere of pressure to be applied.

Equipment Used for FTIR Analysis

Spectrum analysis using Fourier transform infrared spectroscopy (FTIR) provides information on the sample's quality and quantity as well as its atomic and molecular energy levels, molecule geometries, chemical bonds in functional groups, and molecular interactions.

(a) (b) (c)

Figure 1. (a) Line diagram, (b)Experimental setup for vacuum bagging process, (c) alkali-treated specimens and untreated alkali specimens.a

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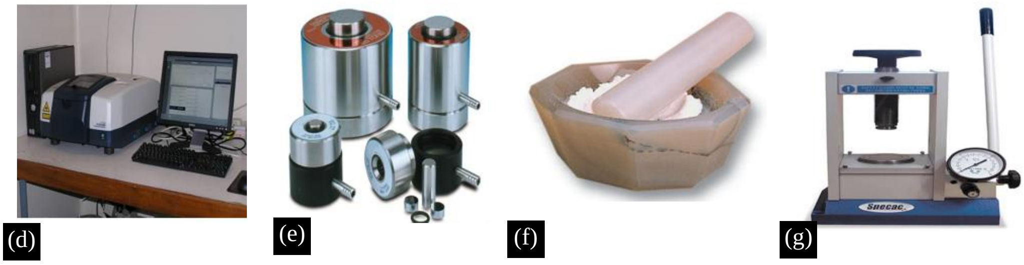

Figure 2. (d)FTIR spectroscopy, (e)mallets, (f) Mortar and pestle, (g) Hydraulic press.

Figure 2 indicates FTIR spectroscopy, mallets, Mortar and pestle and Hydraulic press. There are three different forms of spectrum continuous energy, usually referred to as wavelength, which is represented as intervals of real numbers. Figure 3 demonstrates the absorption of light refers to the process in which a material absorbs a certain kind of energy carried by light. On the other hand, emission range of electromagnetic spectra refers to the range of energy spectrum in which a substance emits or radiates energy. When it comes to identifying functional groups and describing information about covalent bonds, FTIR is an excellent analytical tool. Materials quality control and contamination analysis are two other areas where FTIR finds use. The ability to examine samples in almost any condition is one of the main benefits of infrared spectroscopy. For instance, by carefully selecting a sample procedure, surfaces, gases, films, fibers, pastes, powders, and solutions may all be investigated. Dispersion infrared spectroscopy is also shown to be useful for investigations of natural fibers in the review. An FTIR spectrometer type Spectra 100 from Perkin Elmer was used to get the spectra. The infrared spectra were acquired between 4000 and 500 cm-1 using a 2 mm/s scanning speed and a resolution of 16 cm-1.The infrared portion of the electromagnetic spectrum contains frequencies that almost any chemical with covalent bonds would absorb. Infrared Absorption is measured in units of dose. This indicates that a certain molecule can only absorb certain types of energy. Infrared (IR) spectra are unique to each molecule because various compounds absorb distinct ranges of energy. The molecular vibrations are excited when they absorb infrared light. Figure 3 describes the FTIR numerical results.

$$E = h\upsilon = hc/\lambda$$

Where, E = Energy of the photon, h = plank's constant = 6.62607×10-34 m^2kgs^{-1} υ = frequency
Normal modes of vibration = stretching bending.

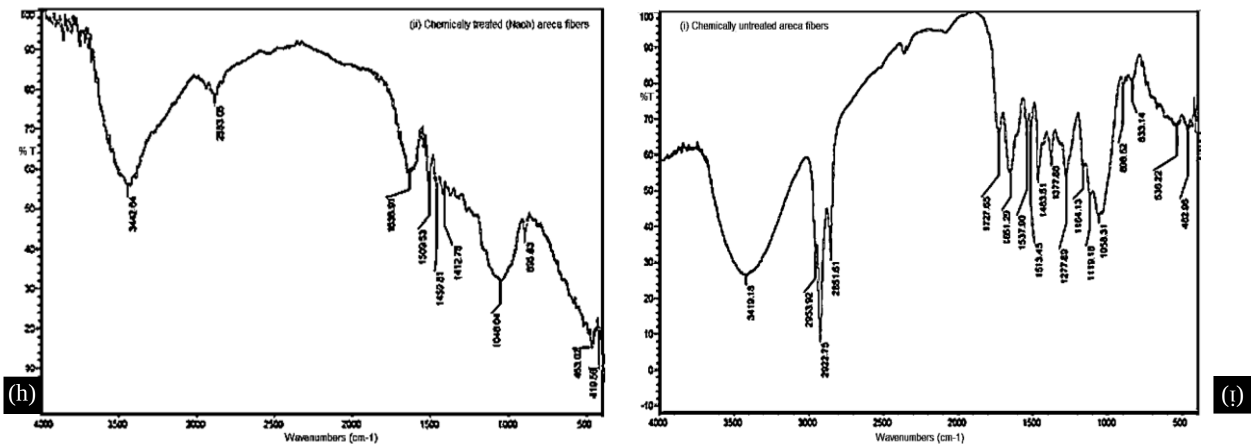

Figure 3. FTIR numerical results, (h) chemical treated with NaOH solution areca fiber, (i) chemical untreated areca fibers.

Table 2 shows the Chemically Untreated Areca fibers Wavelength of Peaks Used for FTIR analysis and Corresponding Functional Groups. Table 3 indicates chemically treated (NaOH) Areca fibers Wavelength of Peaks Used for FTIR analysis and Corresponding Functional Groups.

Table 2. Chemically Untreated Areca fibers Wavelength of Peaks Used for FTIR analysis and Corresponding Functional Groups.

S. no	Wavenumber per cm^{-1}	Phenomenon	Functional group
1.	1277- 1058	CO Stretch	Ethers
2.	1727- 1463	CC stretch	Alkenes
3.	2922-2851	CH stretch	Alkyle groups
4.	2953 -3419	OH Stretch	Alcohols, water

Table 3. Chemically treated (NaOH) Areca fibers Wavelength of Peaks Used for FTIR analysis and Corresponding Functional Groups.

S. no	Wavenumber per cm^{-1}	Phenomenon	Functional group
1.	695-1048	CO Stretch	Ethers
2.	1412-1500	CC stretch	Alkenes
3.	1858-2883	CH stretch	Alkyle groups
4.	3442-3500	OH Stretch	Alcohols, water

Tensile Test on UTM Machine

Universal testing machines (UTMs) do tensile testing, a fundamental method for evaluating materials' mechanical properties. By providing useful information on how a material behaves under axial loading, the stress-strain curve and associated properties help in material selection and design. To ensure the reliability and safety of various engineering structures and elements, it is essential to understand these qualities. A tensile test conducted using a UTM should concisely and clearly report the experiment's findings, with a focus on material properties, stress behaviour, and practical consequences. Here, different loading condition is observed for test the specimen's alkali treated specimens to untreated composite materials. Table 4 shows the Alkali treated composites with different filler percentages. Table 5 indicates the Un-treated composites with different filler percentages.

Table 4. Alkali treated composites with different filler percentages.

S.no	% of micro silica powder added to specimen (Alkhil treated fibers)	Maximum Load(N)	Load atbreak (N)	Tensile strength (MPa)	Young's modulus (MPa)
1	A_1- 5%	4856.29	4450.59	161.88	9449.46
2	A_2- 10%	4711.13	4655.15	157.04	9264.12
3	A_3- 20%	6632.82	6626.60	224.09	8913.81

Table 5. Un-treated composites with different filler percentages.

S.no	% of micro silica power added to specimen (Un- treated fibers)	Maximum Load (N)	Load at break (N)	Tensile strength (MPa)	Young's modulus (MPa)
1	U_1- 5%	5885.39	4908.50	196.18	7603.72
2	U_2- 10%	5093.62	4912.51	169.79	7576.80
3	U_3- 20%	6642.52	5025.42	221.42	9558.01

Figure. 4 shows that different alkali treated composite fibers (A1, A2, and A3) containing various filler percentages (A1, 5%, A2, and A3, respectively) performed better under different maximum loading conditions, with A3 having the best breaking load. From A1 to A3, the braking load increased steadily. There is a clear relationship between the loading conditions and the tensile strength, with tensile strength being highest at A1, falling at A2, and ultimately increasing at A3. In contrast, the alkali-treated Young's modulus decreased from A1 to A3 with time. According to the property of elastic materials, the maximum measurement is noted at 5%. The fact that it may be stretched and deformed in relation to the ratio of tensile stress to tensile strain is proven by the property of young's modulus. A location where a certain amount of force is exerted on a given region.

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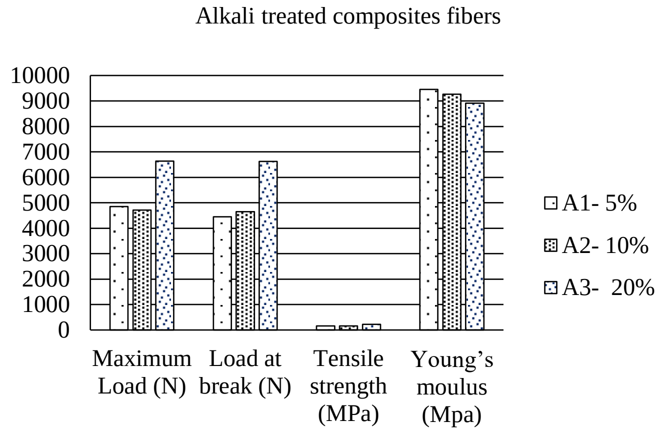

Figure 4. Alkali treated composites fibers

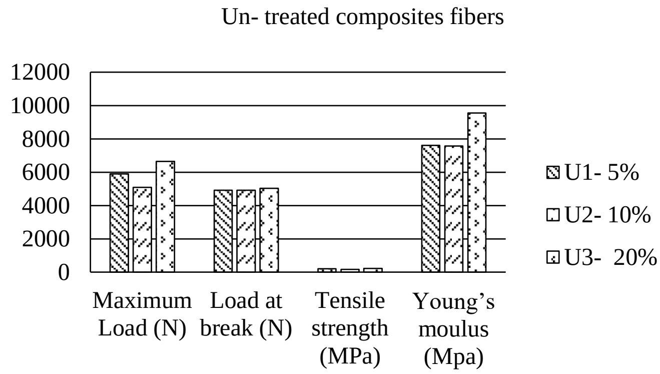

Figure 5. Un- treated composites fibers.

Figure 5 demonstrates that varying percentages of untreated composite fibers (U1, U2, U3) with micro silica power result in varied percentages of filler (5%, 10%, and 20%, respectively). Here, additionally varied loading condition was consider based on study findings. In this varied loading scenario, the breaking load is with standing at larger at U3. Even despite with different in loading situation from U1 to U3. Tensile strength is the highest amount of stress which a material can be endure before breaking point when is is stretched or pulled this will measure the mechanical attribute of the material. The young's modulus values are changing gradually from U1 to U3. At U3 20 %, maximum measurement is seen based on stiffness of an elastic material attribute has been indicated as 958.01 MPa.

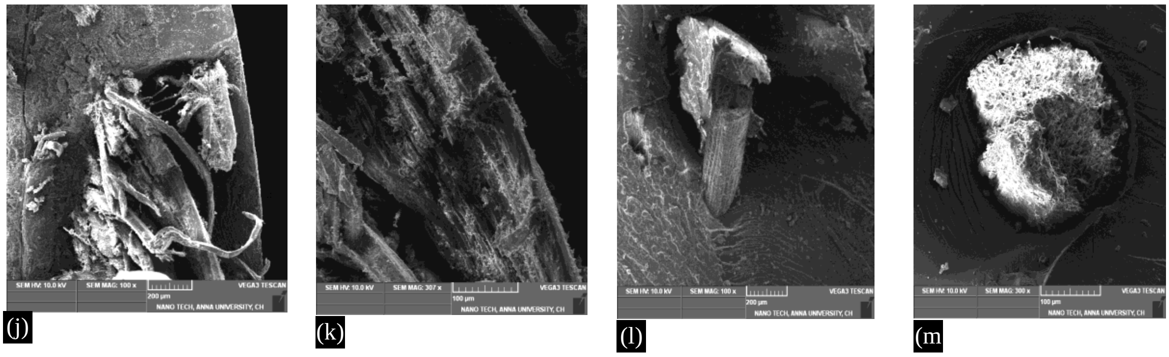

Figure 6. (j) & (k) Morphology of 10 % micro silica powder resin/areca fiber composite without alkali treatment observed with SEM: (j) 100× magnification and (k) 307× magnification. (l) & (m) Morphology of 10 % resin/areca fiber composite with alkali treatment observed with SEM: (l) 100× magnification and (m) 300× magnification.

Morphological Analysis

In scanning electron microscopy analysis, the areca fiber composite specimen's broken surface morphology was analysed using a SEM machine. With the aid of this device, which offered a graphical interface, it was possible to see the fracture surface morphology of the failure bonding behaviour between the matrix and composite specimens more clearly. Morphologystudies were conducted to examine the effects of alkali treatment on areca fibers. SEM measurements were taken on both the untreated fiber and the surface of the fiber that had been subjected to tensile testing. Figure.6 (j) and (k) show the results of the untreated areca fibers with 10% micro silica powder addition, while Figures (l) and (m) show the chemically treated areca fibers with 10% micro silica powder addition, respectively. The alkali treatment eliminates the waxy epidermal tissue and the adhesive properties of pectin, lignin, and hemicelluloses that hold the fiber bundles together. A rough surface, removed trichomes and hair-like growths, braked fibers, gaps between fibers, pores on the surface of the fibers, and a hole in the middle of the fibers were all visible in the scanning electron micrograph (j) of the alkali-treated fiber. The fibers had also lost their chemical release coating. It is possible to distinguish between the chemical layer and the SEM image (l) and (m). Since the chemlease coating on natural fiber surfaces hinders effective interfacial bonding between the fibers and the polymer matrix, removing it, along with pectin and other low-molecular weight components, may enhance the contact between the fibers and the resin. Using a scanning electron microscope, the morphological study of the areca fiber-reinforced composite was carried out under maximal condition. The morphological study of the laminate revealed that the fiber and resin adhered well.

Indeed, there are multiple ways in which surface morphology can affect the mechanical properties of composites:

The adhesive capability of a composite can be influenced by its surface qualities. The wettability of a composite can be influenced by its surface qualities. The biocompatibility of a composite material can be influenced by its surface characteristics. Composites with a more homogeneous pore structure have better thermal conductivity. Excellent tensile strength can be achieved by using a composite with a surface porosity of around 41%. Excellent wear resistance can be achieved by using a composite with a surface porosity ranging from 40 to 50%. The mechanical strength of a composite material is influenced by the adhesion and interaction of its constituent parts.

CONCLUSION

In this investigation the stem of the areca fiber is used and araldite as the resin, chemlease 7891 EZ as releasing agent to create the experimental inquiry of the Areca palm fiber-reinforced composite laminate. The areca palm stem is cut into the necessary pieces and processed chemically with alkaline solution to remove the fibre. The laminated are prepared by using vacuum bagging process laminates are chemically treated was compared untreated areca fibers with different filler percentage of adding micro silica powder with 5%, 10% and 20 %

Prepared laminates by using a 60:40 F/R ratio (fibre to resin ratio). 20% epoxy resin (araldite), 10% filler, and 10% releasing agent make up to 40% of the polymer combination. In mechanical tensile testing material's behaviour under axial loading condition due to varying loading conditions tensile strength is gradually increased with different filler ratios 5 %, 10%, 20% of Alkali treated composites. In the chemically untreated composites tensile strength was not uniformly increasing. In this investigation Alkali treated composites performed good tensile strength.

Making laminates into powder form, a Fourier transform infrared spectroscopy (FTIR) test is carried out. This can assist locate organic and some inorganic substances that might be a source of product contamination or malfunction. In essence, FTIR analysis evaluates a sample's absorption of infrared light at various wavelengths to ascertain the material's molecular composition and structure by exposing it to infrared radiation (IR). The Fourier transform spectrometer uses conversion to get the absorbance level at each wavelength from the broad-band light source's raw data.

SEM analysis is carried out to shown the morphological analysis of areca fibre-reinforced composite with 10% of micro silica powder, resin and areca fibers are chemically treated with NaOH solution compared with chemically untreated fibers. In morphological analysis it is observed that fiber and resin adhered well and few fibers were braked, some fibers are having small blow holes and porosity was generated on the surface.

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