Mechanical and Wear Performance Evaluation of Natural Fiber/Epoxy Matrix Composites

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Fibers collected from the husk of areca nut trees were chopped to a length of 30 mm and were either used as such or subjected to alkaline treatment by immersion in a 5% sodium hydroxide (NaOH) solution. The untreated and treated fibers were investigated using thermogravimetric analysis (TGA) before the fabrication of composites using an epoxy matrix. Different amounts of fibers were introduced in the matrix, fabricating the composite by compression molding. The composites were subjected to tensile, flexural, and Charpy impact and Shore D hardness testing, which all demonstrated the considerable advantage obtained with the growing quantity of fibers, especially when employing treated fibers, except in the case of hardness, where limited advantages were encountered. Wear tests were carried out on treated fiber composites and the surface morphology of the worn-out samples was studied, which also demonstrated the improvement in fiber-matrix bonding obtained with the growing amount of fibers. The main limitation of the fibers was their low elongation even after treatment. The fibers hardly reached 4%, which might represent a quite normal value for this kind of fibers, possibly due to with tendency to fibrillation. This would somehow compare these composites with others with similar amounts and lengths of natural fibers.

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INTRODUCTION

Sustainability considerations increasingly suggest the use of renewable materials for the fabrication of composites as the replacement for synthetic ones, such as glass fibers (Thakur *et al.* 2017; Karthik *et al.* 2024; Palaniappan *et al.* 2024b; Satankar *et al.* 2024). A large number of lignocellulosic fibers have been used for the reinforcement of polymer composites, and their varieties and the related possibility of choice are increasingly growing, depending especially on the region of production and application requirements (Tabrej *et al.* 2018; Rangappa *et al.* 2022; Kurien *et al.* 2023; Sumesh *et al.* 2023). Among these, there are fibers originating, hence extracted from plant bast, leaf, seed hair, fruit hair, stalk, and bark. A general classification is offered in Fig. 1 where some examples of fibers

for each category are listed and the position of areca is highlighted.

The areca (*Areca catechu*) or betelnut nut tree belongs to a species native to the Philippines. Areca is a palm tree widely cultivated in tropical countries, including southern China, Taiwan, India, Bangladesh, the Maldives, *etc*. Areca nuts are the principal product, together with husk, while leaf stalks serve as the primary source of fiber extraction (Croucher and Islam 2002; Almeshaal *et al.* 2022; Palanisamy *et al.* 2022a; Govindarajan *et al.* 2024). In some other palm fibers, it is possible to have different fibrous products, namely from the leaf sheath (Shanmugasundaram *et al.* 2018) and the fruit hairs, which provide a sort of husk, whose significance in applications other than for materials, such as oil sorption, has also been investigated (Nik Ab Lah *et al.* 2021; Senthil and Murugananthan 2022; Mylsamy *et al.* 2024). The composition of these fibers as received has also been reported, though the cellulose content might be variable: values of 53% for alpha-cellulose, 33% for hemicellulose, and 7% for lignin were obtained (Yusriah *et al.* 2012). In the case of areca husk, 43.3% of cellulose, 29.2% of hemicellulose, and 12.6% of lignin were instead measured (Vardhan *et al.* 2024). The common factor is the considerable presence of hemicellulose, which suggests the usefulness of fiber treatment to improve their mechanical performance. In particular, alkali treatment using sodium or potassium hydroxides is likely to enhance fiber-matrix compatibility due to the removal of loose matter and regularizing the surface of the fiber, providing a stronger adhesion (Fiore *et al.* 2015).

The fiber length obtained is typically in the range of approximately 50 mm, while the density can be very low, down to 0.3 or less, due to substantial lumens in the section (Kamath *et al.* 2017). Before its possible use in composites, the effect of chemical treatment with potassium hydroxide (KOH) on areca nut husk was elucidated, clarifying that the pressing of husks following 2.5% KOH alkali pretreatment led to the easiest detachment of fibers from the husk (Deshmukh *et al.* 2019).

Various studies have been reported in the development of areca nut-based composites for structural applications. Muralidhar *et al.* (2019) reported on the tensile, flexural, and impact performance of epoxy composites with areca husk fibers of different coarseness (Ramasubbu *et al.* 2024; Eashwar Raaj *et al.* 2024). A study on unsaturated polyester/areca nut husk fibers highlighted the potential for the production of sound absorption panels but clarified that their introduction in amounts of more than 10 wt% could lead to limited effectiveness in improving the tensile strength of the resin (Jayamani *et al.* 2014; Palanisamy *et al.* 2022b). This can be because, despite the treatment, the limited length of areca nut husk fibers does not result in sufficient interface soundness. A higher global quantity of reinforcement has been obtained by mixing in an epoxy hybrid composite of areca nut husk fibers with tamarind fruit ones, though again with not fully consistent tensile results (Girisha *et al.* 2012; Arumugam *et al.* 2022). On the other side, the effect of different treatments (sodium hydroxide, potassium permanganate, benzoyl chloride, acrylic acid) was much more perceivable, even for higher fiber loadings, for Charpy impact strength. However, the data consistency appears dubious, for the large increase in performance measured only for the 60 wt% fibers composites, whatever the treatment (Dhanalakshmi *et al.* 2015).

With these considerations, areca nut husk fiber composites have some potential, especially in that the filler represents an easily available agrowaste source. However, this has been scantily explored so far. In the current study, laminates containing areca nut husk fibers were fabricated utilizing the compression molding technique. The idea is to produce boards with a significant amount of bio-based content and to evaluate their capability to

withstand the wear-out process. Chopped areca nut fibers were added in varying weight percentages of 10, 15, 20, and 25% over the weight of epoxy resin for this detailed investigation. Different characterizations, which include testing of mechanical, tribological, and thermal properties and the observation of the morphological characteristics of worn-out laminates were conducted.

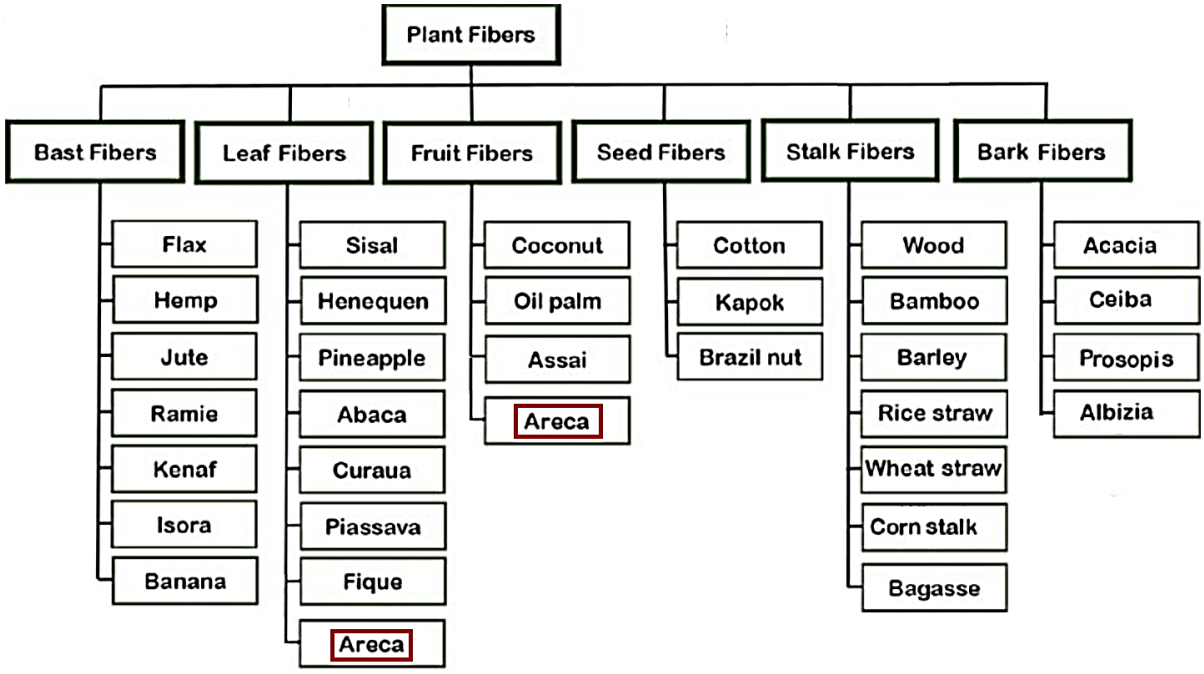

Fig. 1. Lignocellulosic plant fibers classification

EXPERIMENTAL

Materials

The epoxy resin and hardener used for this work are LY556 and HY951, procured from Vruksha Composites and Services, Tenali, Andhra Pradesh. The resin-to-hardener ratio was 10:1. Areca nut fibers were collected from the local plantation in Andhra Pradesh. The plantation yielded matured areca nut husk that had been dried. To release the fibers, the dried husk was immersed in fresh water for 24 h. The dirt particles adhered to the fibers of the water-soaked areca nut husk so that the fibers were washed with fresh water afterward. To facilitate the chemical retting procedure, in one of the two sets of fibers, the areca nut husk was immersed in a 5 wt% by sodium hydroxide (NaOH) solution for 4 h at ambient temperature.

To eliminate any trace of the treating agent from the surface of the fibers, the alkali-treated husk was rinsed in distilled water. To lessen the moisture absorbed by the areca nut fibers, the cleaned areca nut husk was exposed to the sun for two days, after which dried fibers were heated in the oven for 3 h at 50 °C. Following this, heated areca nut husk fibers were removed and stored in sealed airtight containers to prevent moisture re-absorption. To regularize their dimension, fibers were chopped down to a length of 30 mm.

Fabrications of Composites

Composite samples were prepared by a simple compression molding technique. Table 1 provides the chemical composition of the fabricated composite materials. The quantities of epoxy and hardener used in making the composites were equal to 300 g and 30 g, respectively. In the process, chopped areca fibers, either as received or treated with sodium hydroxide (NaOH) (5 wt%), were placed in a mold with cavities fitted to size to fabricate a laminate with dimensions 200 × 200 × 6 mm. The mold was then pressed with a pressure of 7 kPa and left to cure for three hours at ambient temperature. After complete curing, the samples were machined with the aid of a water jet into ASTM specifications. Figure 3 shows the images of the various composite samples prepared using water jet cutting. Eight combinations were used in the process, with amounts of fibers equal to 10, 15, 20, and 25 wt% with and without alkali treatment.

Table 1. Codes, Compositions, and Density of the Three Series of Composites Tested

Composite Code	Series	LY556 (g)	HY951 (g)	Areca nut husk fibers (g)	Density (g/cm^3)
P	Untreated (NT) NaOH treated (T)	300	30	30	1.07
Q	Untreated (NT) NaOH treated (T)	300	30	45	1.056
R	Untreated (NT) NaOH treated (T)	300	30	60	1.042
S	Untreated (NT) NaOH treated (T)	300	30	75	1.028

Mechanical Testing

The tensile specimens were prepared according to the ASTM D638-14 (2018) (Laureto and Pearce 2018) standard, following the parameters indicated in it, as regards gauge length, crosshead speed, *etc.*, therefore using a gauge length of 50 mm, and performing the tests in displacement control mode using a crosshead speed of 5 mm/min.

The flexural specimens were prepared according to the ASTM D790-17 (2017) standard (Ishak *et al.* 2010). The bending strength of the specimens was evaluated using the three-point test in a UTM machine. The specimens were held on two supports in a flat-wise position and a load was applied in correspondence with their geometrical center. The span length of the supports was fixed at a span-to-depth ratio of 16:1. Load was applied to the samples using a crosshead speed of 2 mm/min.

The specimens for the impact test were prepared as per the ASTM D256-10 (2019) (Gadzama *et al.* 2019) standard and supported in Charpy mode. The pendulum in the impact testing machine strikes the specimen multiple times throughout the testing process until it breaks or fractures. Each specimen had a notch with a depth of 2.5 mm.

The Shore D testing machine performed the hardness tests on the prepared samples as per ASTM D2240 (2021) (Ganapathy et al. 2021) standard. The specimen was pierced with the durometer indenter's foot to obtain the values of hardness.

Tribological Testing

A pin-on-disc (POD) machine (TR-20 LE by Ducom, Karnataka, India) was used to perform the dry sliding wear testing, which was only carried out with composites with treated fibers. Regulations established by ASTM G99-05 (2010) (Khan *et al.* 2017) were

followed in producing the specimens. A total of 30 straight pins with dimensions of 50 × 5 mm and a length of 30 mm were used in the experiment. 10, 15, and 20 N were applied as loads to the disc, which was moving at a speed of 3 m/s.

Before the experiments, abrasive silicon carbide (SiC) sheets were used to polish these specimens using SiC paper No. 900, and then counter-faced before the trials (SiC paper No. 1200). Acetone was used to clean these specimens, used to test, which were later allowed to air until dry once they had been cleaned. The difference between the weights before and after the dry sliding test calculates the weight loss for the composite specimen. The specimens were weighed with an electronic scale (AUW. 220D by Shimadzu, Kyoto, Japan). The weights obtained correlated well with density data, which are also provided in Table 1. In particular, those reported on areca nut husk fibers indicated for them a density equal to 0.78 g/cm^3 and for epoxy resin, a density of 1.1 g/cm^3 (Binoj *et al.* 2016). Other data on areca nut husk fiber densities indicated much lower values, as low as 0.19 g/cm^3, and were considered irrelevant for the purpose (Yusriah *et al.* 2014; Ashraf *et al.* 2024). The explanation for this is that the large diameters (in the region of 500 microns) of the fibers measured in that case indicated that measurements were carried out on bundles with large internal voids and possibly approximating the fibers to cylinders.

The weights obtained were in the range of 0.81 ± 0.02 g for P samples, 0.79 ± 0.02 g for Q samples, 0.77 ± 0.02 g for R samples, and 0.75 ± 0.02 g for S samples, substantially confirming the density values from (Binoj *et al.* 2016; Goutham *et al.* 2023; Karuppiah *et al.* 2020; Santulli *et al.* 2022). It was decided to measure the absolute weight loss for the different samples, in the understanding that, as far as wear is concerned, significant differences would only be those that exceeded a few percent.

A friction tester was also employed to measure the ratio between the friction force and the gravity force on the various samples, defined as the coefficient of friction (COF).

Spectroscopical Properties

The spectral analysis was carried out using a Perkin Elmer Spectrum Two FTIR spectrometer, which used an attenuated total reflection contact sampling method. The instrument used had a spectral resolution of 0.5 cm^{-1}. Data were collected in a range between 400 and 4000 cm^{-1}.

Analysis of Thermophysical Properties

Thermogravimetric analysis (TGA) is one of the most sensitive thermal studies, and it is widely used to investigate the effect of thermal stability and structural dependence of areca nut husk fiber samples, measuring the weight shift that occurs when a specimen is heated up. The technique was used to find the thermal effectiveness of a specimen and the proportion of volatile components, using a STA6000 system by Perkin-Elmer, Waltham, Ma., USA. For this purpose, samples with an approximate weight of 40 mg were placed in an alumina pan and analyzed in an air atmosphere from 40 to 550 °C, using a heating rate of 10 °C/min. The onset temperature (Td) of both treated and untreated fibers was found from TGA results with the tangent line drawn through the curve. Similar works were done by Liu *et al.* (2001).

Worn Samples Morphological Characterization

Analysis of the scanning electron microanalysis of worn-out surfaces epoxy polymer composites reinforced with areca nut husk fibers was carried out using a scanning electron microscope (SEM-Zeiss Sigma VP, San Diego, Ca., USA) with an accelerating

voltage range between 0.2 and 30 kV. Samples were sputter-coated using gold before analysis.

RESULTS AND DISCUSSION

Areca Nut Husk Fiber Thermal and Chemical Characterization

The experimentation is first aimed at the comparison of the temperature degradation profile between untreated and treated areca nut husk fibers using thermogravimetric analysis (TGA), followed by their chemical characterization using Fourier transform infrared spectroscopy (FTIR) to qualitatively assess the modification of their composition as an effect of the treatment.

In particular, with thermogravimetric analysis, it was observed that the treatment applied on areca nut husk fibers resulted in a reduction by around 20 °C of the peak degradation temperature of the biomass (Fig. 2), which is likely due to the partial dissolution of lignin. This was calculated by the method suggested by Liu *et al.* (2001), Palanisamy *et al.* (2024), and Shanmugasundaram *et al.* (2018) and applied to biomass waste in Sivasubramanian *et al.* (2021) and Johny *et al.* (2023), for comparison between untreated and treated material. A substantial decrease to almost zero of the residues was obtained at 550 °C. This is also an expected result, which has been reported on the degradation of rice husk after alkali treatment and may be attributed to the dissolution of lignin and some hemicellulose (Ndazi *et al.* 2007; Sivasubramanian *et al.* 2021).

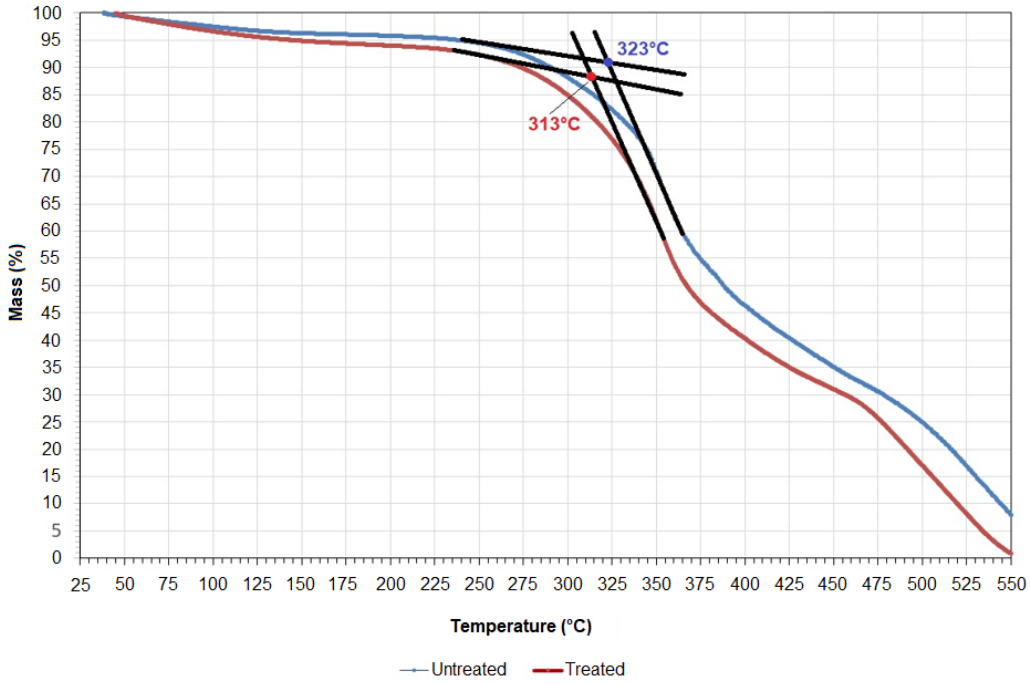

Fig. 2. Thermogravimetric analysis on untreated and alkali treated area nut husk fibers

On the other hand, comparing FTIR spectra on untreated and treated fibers suggested that as the result of treatment cellulose content in the fibers had increased (Fig. 3). The C-H asymmetric deformation and CH_2 symmetric cellulose bending in NaOH-

treated areca fibers showed a peak at 1370 cm^{-1} (Sumesh and Kanthavel 2022; Palaniappan *et al.* 2024a). This was not visible in untreated areca fibers. The surface treatment provided ionizing hydroxide groups and created alkoxide in the areca fibers, neglecting hydroxide groups. The peaks in 3277 cm^{-1}, 3302 cm^{-1} at untreated and treated areca fibers are shown by stretching vibrations due to -CH and -OH groups (Sumesh *et al.* 2021). The peaks at 1634 cm^{-1}, 1642 cm^{-1} show bending mode for water absorption in the areca fibers. The peaks at 1022 cm^{-1}, 1025 cm^{-1} supply proof of pyranose vibration in treated and untreated areca fibers, suggesting that lignin does not completely disappear (Alshahrani and Arun Prakash 2022).

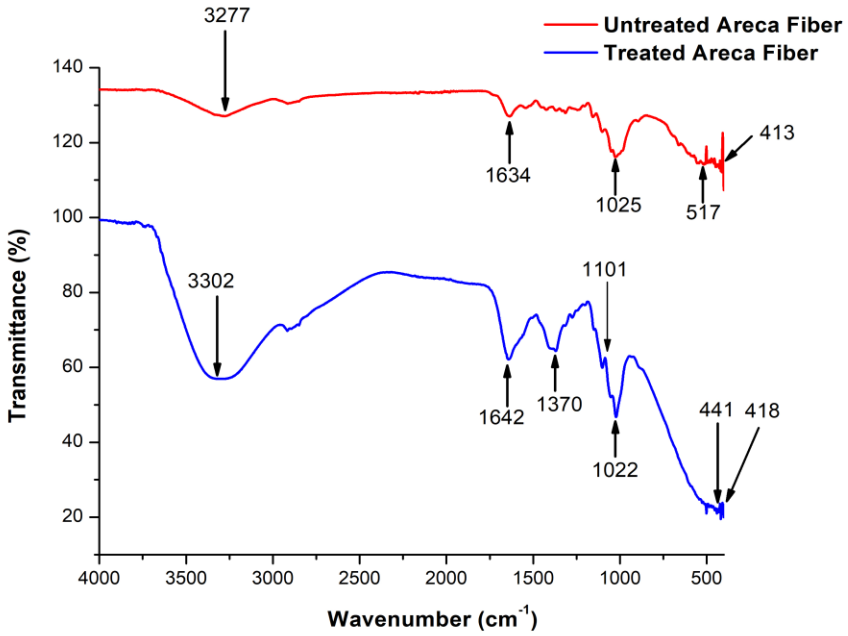

Fig. 3. FTIR results of treated and untreated areca fibers

Areca Nut Husk Fiber/Epoxy Composites Mechanical Characterization

Following fiber characterization, composites were fabricated in the various configurations exposed in Table 1, and on these, mechanical testing has been carried out. More specifically, in Figs. 4 to 6, tensile, flexural, Charpy impact, and hardness performance are reported, both on composites with untreated and treated fibers. Fiber treatment is normally advantageous for composite performance, since it removes the waxy substances not able to withstand any loading. In the case of hardness, the benefits of treatment were comparatively lesser. This indicates that the insertion of treated fiber has hardly any effect on the surface properties of the composite. After these general considerations, attention is given to treated fiber composites, which were reasonable for better applications.

The tensile performance (Fig. 4) of composites, though much lower than what was obtained with the pure epoxy resin employed (as from data reported in (Karuppiah *et al.* 2022; Naik *et al.* 2022), a value of 84 MPa) grows with the increase in areca fiber incorporation from 10 to 20 wt%. The elongation to break is limited to approximately 4% maximum, which appears to be much lower than what can be obtained on areca nut husk fibers, as reported by Deshmukh *et al.* (2016). Here, an elongation to break of up to 22% has been measured, which is likely to include an extensive fibrillation effect. It is suggested that the properties of epoxy resin are still dominant over that of the fibers. Introducing more

fibers does not change their elongation to break, and this is possibly due to a limited occurrence of pull-out, as is often the case for natural fibers with low aspect ratios (Kwon *et al.* 2014).

The alkali treatment of areca fibers had a large influence in enhancing the elongation and the tensile strength of epoxy-based composites up to 20 wt% fiber content. The main effect of alkali is the loosening of non-structural parts of lignocellulosic material (Hill and Hughes 2010). In contrast, the higher fiber addition in the natural fiber at 25 wt% declines the tensile properties of epoxy-based composites. It might be suggested that surface deformation and uneven distribution of natural reinforcements lead to this decline by excessively close packing of the fibers, as reported elsewhere for palms (Yang *et al.* 2017). The tensile modulus results are more dependent on the wt% of areca fibers incorporated, although the benefit of introducing 25 wt% of fibers is doubtful.

The above trend is substantially repeated for flexural performance (Fig. 4), where a substantial decrease from the pure epoxy resin is observed.

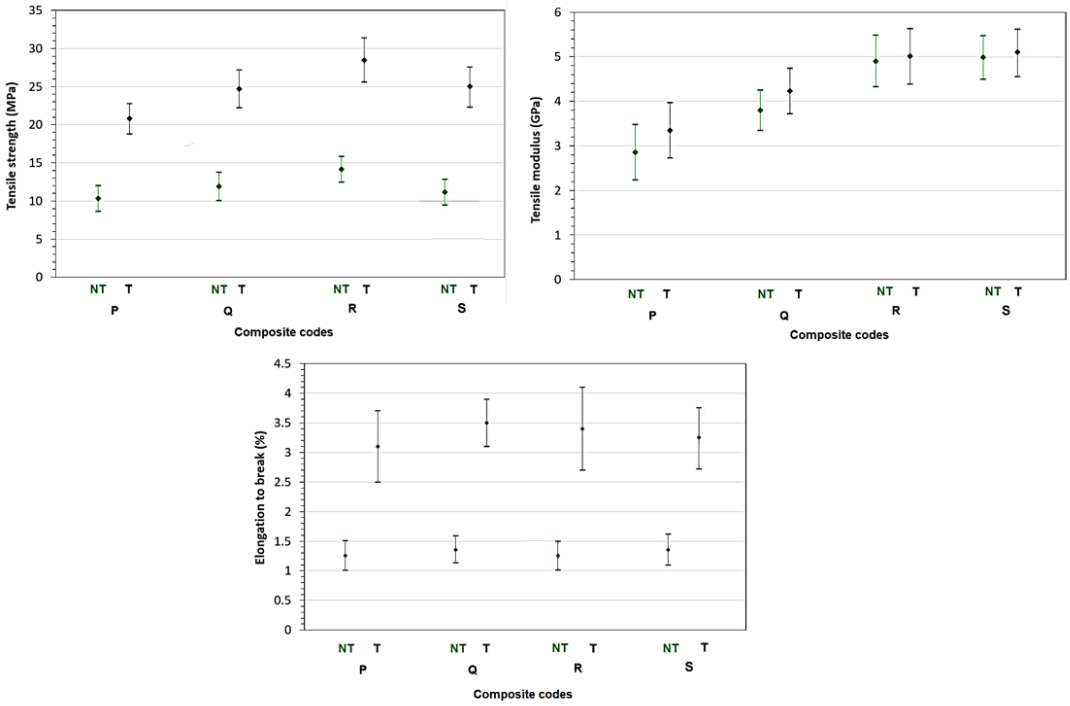

Fig. 4. Tensile data for all areca nut husk fiber/epoxy composites (NT = with untreated fibers; T = with treated fibers)

A value of 124 MPa for flexural strength of pure epoxy resin is reported and impact strength with an increase in properties by surface treatment and fiber incorporation (Fig. 5a) (Raghavendra and Lokesh 2019; Hanan *et al.* 2023; Palanisamy *et al.* 2023). Both the treatment and reinforcement addition have equal importance in enhancing the flexural strength of the epoxy-based composites. The influence on Shore D hardness results was less consistent with the different factors introduced (Fig. 5b). This is likely to indicate that the surface properties were varied in the composites causing variations in the results. The hardness properties increase with higher fiber incorporation (20 wt%). However, the hardness values obtained are higher than for other epoxy composites reinforced with the same amount of other types of natural fibers, such as *Typha angustifolia* (Mohankumar *et al.* 2022).

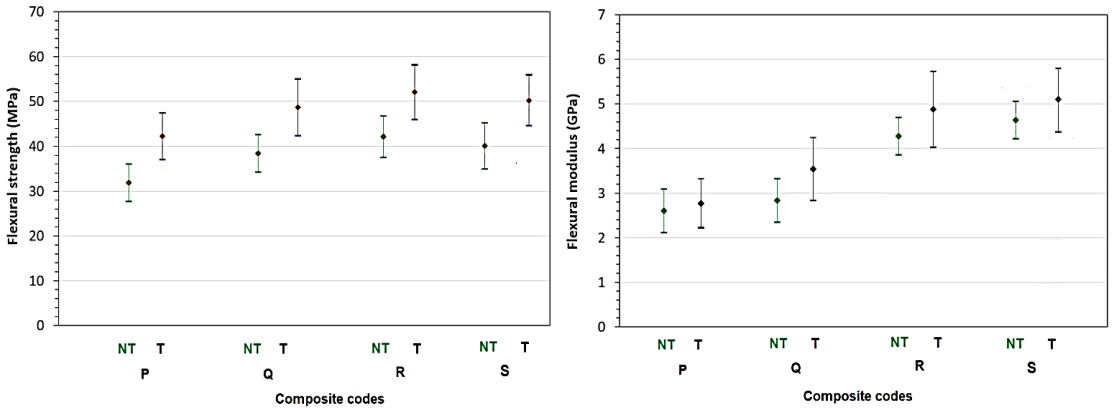

Fig. 5. Flexural data for all areca nut husk fiber/epoxy composites (NT = with untreated fibers; T = with treated fibers)

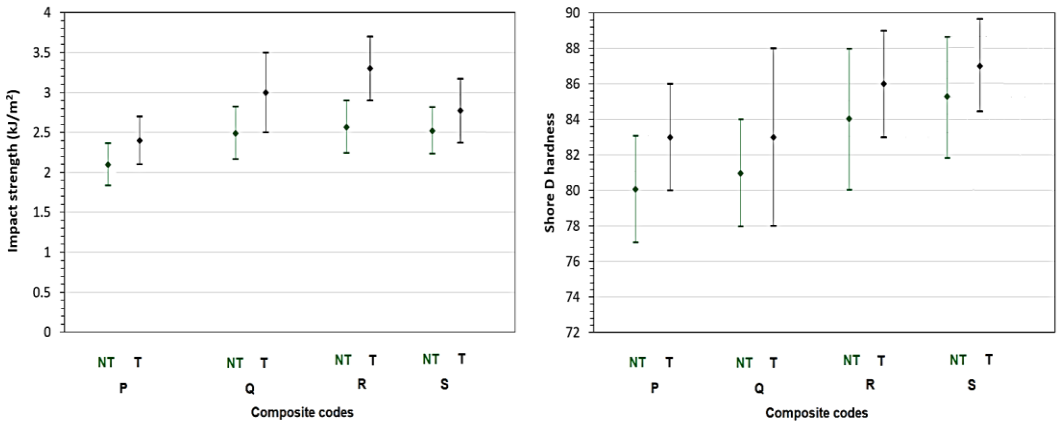

Fig. 6. Charpy impact (left) and Shore D hardness (right) data for all areca nut husk fiber/epoxy composites (NT = with untreated fibers; T = with treated fibers)

To conclude the evaluation of the mechanical performance, morphological observation of tensile fracture was carried out by electron microscopy, so as to further evaluate the effectiveness of alkali treatment. The SEM observations following tensile testing offered (Fig. 7) better results after the NaOH treatment and with optimum fiber amount incorporation. The 25 wt% areca fiber composite indicated high surface deformations resulting in fiber breakage, matrix cracking, and voids declining the mechanical properties of epoxy-based composites. The 20 wt% treated areca fiber composite yielded improved interfacial fiber-matrix adhesion and that added to the properties. Surface treatment provided better passage of epoxy resin through the fiber with the surface roughness created by NaOH treatment. All these enhanced the mechanical properties of the composites.

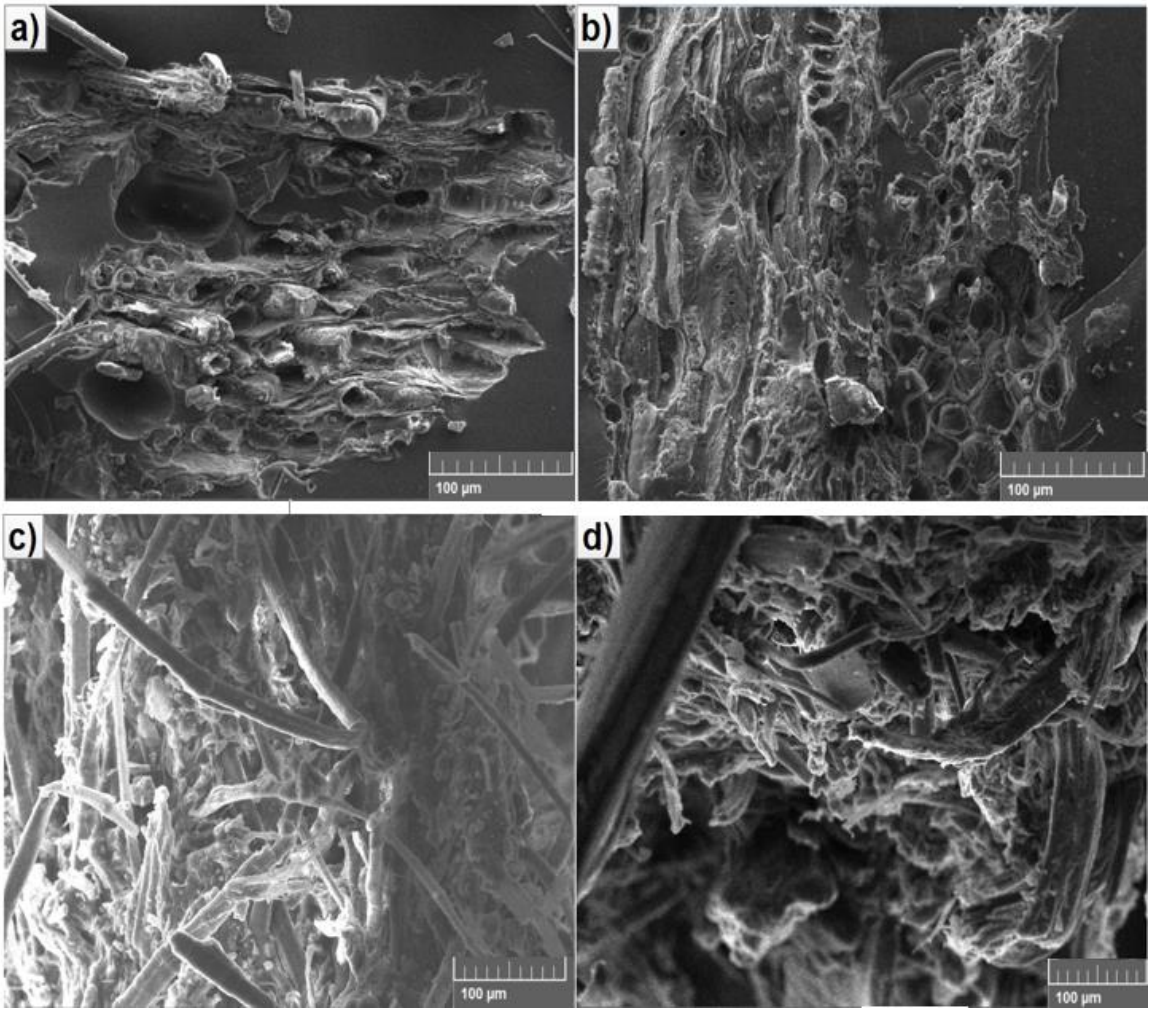

Fig. 7. Scanning electron microscope analysis after tensile testing a) 10 wt% areca fiber untreated, b) 25 wt% areca fiber untreated, c), d) 20 wt% areca fiber treated all with epoxy-based matrix

Areca Nut Husk Fiber/Epoxy Composites Tribological Characterization

The previous mechanical results indicated that alkali treatment at 5 wt% had a large influence in enhancing the mechanical properties of areca nut husk-epoxy composites. This suggested the use of only alkali-treated natural fibers for further study on the tribological applications. The wear reduction effect with the number of reinforcement fibers was consistent, as reported in Fig. 8. The results showed an increase in the wear loss (g) due to the usage of higher loads ranging from 10 to 20 N. The higher loads created a high-pressure zone in the counter disc that subsequently led to non-negligible wear loss. Wear loss bears some direct proportionality to the applied load, so the lower the load applied, the lower the wear loss produced. Effective control of the erosion during fatigue was observed with the addition of alkali-silane-treated areca fiber to the cardanol oil matrix (Gangwar and Pathak 2021). In the present case, the coefficient of friction (CoF) results reported a substantially higher abrasion (Table 2) with an increase in the fiber content up to 25 wt%, due to an increase in the hardness values and high pressure in the counter specimen for applied loads of 10 and 15 N. At 20 N, the effect is less evident, which may be attributed to the fact that increase in the load creates high temperature in the sliding part of the composites with high friction rate, as observed already on biomass studies in (Jayabalakrishnan *et al.* 2021).

The micrographs in Fig. 9 show improvement based on increased reinforcement. In general, the introduction of a larger amount of fibers produces a marked difference in the modes of fracture of the composites. The abrasion behavior of epoxy resin offers the formation of pits and dimples due to the resin adhesion to the tool, as indicated in Fig. 9a, and is a major cause of weight loss (Dhanalakshmi *et al.* 2015). The presence of debris is always observed, such as in Fig. 9b, however, this is reduced with the introduction of a higher amount of fibers, with bonding still being satisfactory with 20 wt% fibers, though not very uniform throughout the sample surface (Fig. 9c). This is not surprising, since even more regular fibers, such as bamboo show a large variability of the proneness to pull out when used in the form of short fibers (Viel *et al.* 2018). The wear weight loss values obtained were comparable to those reported in Basavarajappa *et al.* (2009).

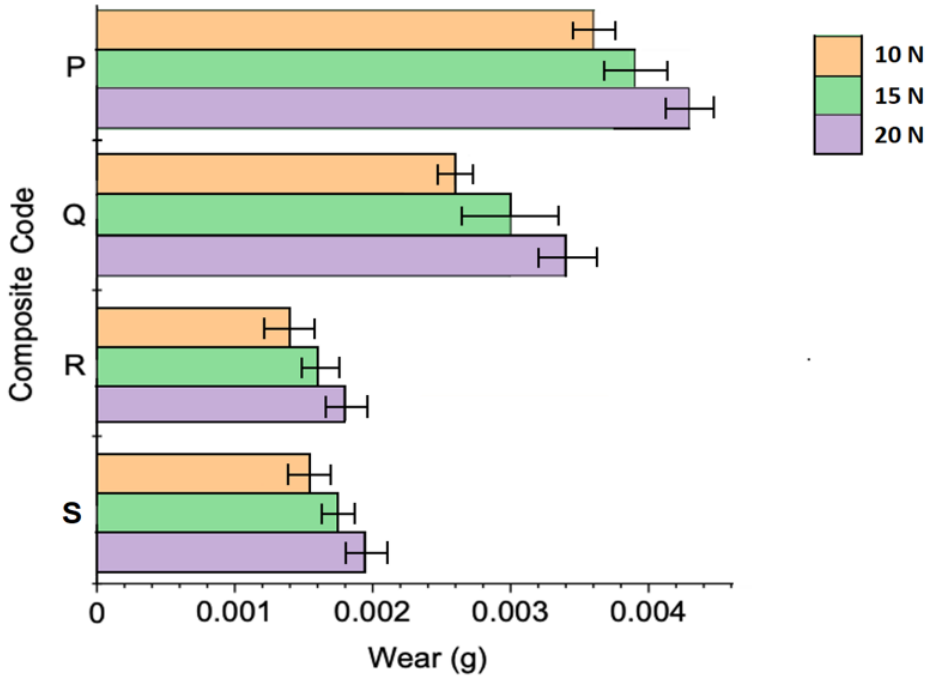

Fig. 8. Wear weight loss data for treated areca nut husk fiber/epoxy composites

Table 2. Coefficient of Friction for Different Composite Series and Load Levels

	P	Q	R	S
10 N	0.242	0.264	0.279	0.294
15 N	0.291	0.314	0.329	0.345
20 N	0.349	0.367	0.369	0.378

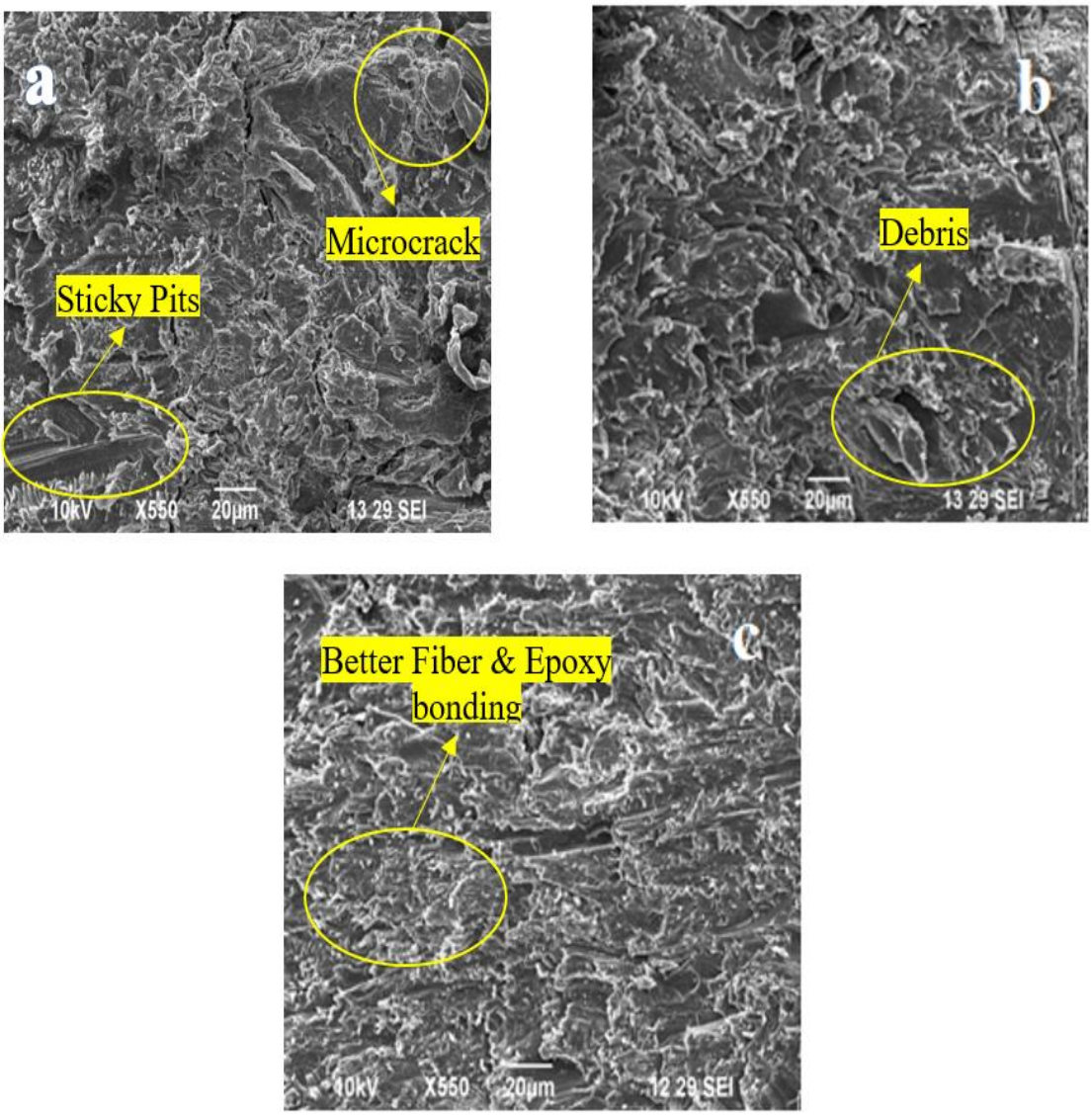

Fig. 9. Scanning electron microscope images with worn-out surfaces of areca nut husk fiber/epoxy composites: (a) 10 wt%, (b) 15 wt%, (c) 20 wt% undergoing to the maximum applied load of 20 N

DISCUSSION ON THE MECHANICAL PERFORMANCE OF ARECA NUT HUSK/EPOXY COMPOSITES

Some final considerations were dedicated to the possibility to compare tensile (Table 3) and flexural data (Table 4) obtained on areca husk nut fiber composites on other composites including natural fibers of the same length, *i.e.*, 30 mm, and introduced in an amount of 20 wt% into a polymer matrix. Areca nut husk composites appear strongly penalized by their limited elongation and possibly irregular geometry, which results in a relatively precocious failure and may limit its application. However, the introduction of a larger amount of fibers would possibly need to be attempted, which would hypothetically improve the effect of treatment. Other treatments would also need to be experimented with in the long run if a sounder mechanical application (and not barely friction-resistant) for this composite had to be proposed. For example, benzoyl chloride, potassium

permanganate, or acrylic acid, though chemically very aggressive, proved effective on the impact strength of areca/epoxy composites, up to high fiber contents, such as 60% (Osman *et al.* 2012).

Table 3. Tensile Performance on Areca Nut Husk Fiber/Epoxy Composites against Composites with the Same Amount of Fiber (20 wt%) and with the Same Length (30 mm)

Fiber	Matrix	Tensile strength (MPa)	Tensile modulus (GPa)	Reference
Areca nut husk	Epoxy	28.5	5.01	Here
Cissus quadrangularis	Unsat. polyester	42	1.17	(Indran *et al.* 2018)
Banana	Epoxy	68	-	(Nguyen and Nguyen 2021)
Indian mallow	Unsat. polyester	26.7	3.25	(Vignesh *et al.* 2021)
Jute	Epoxy	78	0.8	(Ramakrishnan *et al.* 2019)

Table 4. Flexural Performance on Areca Nut Husk Fiber/Epoxy Composites against Composites with the Same Amount of Fiber (20 wt%) and with the Same Length (30 mm)

Fiber	Matrix	Flexural strength (MPa)	Flexural modulus (GPa)	Reference
Areca nut husk	Epoxy	52.1	4.78	Here
Cissus quadrangularis	Unsat.polyester	65	1.18	(Indran *et al.* 2018)
Banana	Epoxy	90.2	-	(Nguyen and Nguyen 2021)
Jute	Epoxy	130	2.8	(Vignesh *et al.* 2021)
10 kenaf/10 jute	Unsat. Polyester	58	3.95	(Ramakrishnan *et al.* 2019)

CONCLUSIONS

Areca nut husk is a typical biomass waste from the food sector, which can be explored for possible use in composites. For this initial purpose, standard fiber treatment with alkali and introduction in epoxy matrix, was considered suitable. The results indicate some pieces of evidence, which are reported as follows:

1. The application of NaOH treatment on areca nut husk fibers allows them to be effectively used on composites. Whilst it is true that the treatment slightly decreases the temperature for their degradation, though remaining largely above temperature for typical composites use. Further studies would possibly propose a less aggressive process, be it chemical or not.
2. From the results of composites testing, it is evident that the areca nut husk fiber/epoxy

polymer composites with an amount of short (30 mm length) random reinforcement introduced of 20 wt% exhibits the highest peak mechanical properties among all the calculated properties. On the other hand, further addition of fibers over that level does not appear to bring additional benefits.

3. The tribological behavior of these composites indicates that the introduction of this amount of fibers also offers the most limited wear.
4. It appears that the production of areca nut husk fiber composites in this configuration hardly compares with other more diffuse fibers. Without a substantial improvement of process production and even despite treatment, they do not appear to be able to successfully compete for this use.

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Data Availability Statement

Data is available on request from the authors.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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