INTERNATIONAL JOURNAL OF AUTOMOTIVE AND MECHANICAL ENGINEERING (IJAME)
ISSN: 2229-8649 e-ISSN: 2180-1606
VOL. 17, ISSUE 4, 8298 – 8309
DOI: https://doi.org/10.15282/ijame.17.4.2020.07.0627

ORIGINAL ARTICLE

Effect of Surface Modification on Mechanical Properties of Buri Palm (Corypha Utan) Fibre Composite Reinforcement

M. Zalinawati[1,2], J.P. Siregar[1,3*], C. Tezara[4], J. Jaafar[1], M.H.M. Hamdan[1], A.N. Oumer[1] and T. Rihayat[5]

[1]Department of Mechanical Engineering, College of Engineering, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia
Phone: +6094246282; Fax: +6094246222

[2]Jabatan Kejuruteraan Mekanikal, Politeknik Sultan Haji Ahmad Shah, Semambu, 25350 Kuantan, Pahang, Malaysia

[3]Centre of Excellence for Advanced Research in Fluid Flow (CARIFF), Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia

[4]Department of Mechanical Engineering, Faculty of Engineering and Quantity Surveying, INTI International University, 71800 Nilai, Negeri Sembilan, Malaysia

[5]Department of Chemical Engineering, Politeknik Negeri Lhokseumawe, 24301, Aceh Indonesia

ABSTRACT – Natural fibre materials are replacing synthetic fibre materials since they are considered as a low-cost, lightweight, and biodegradability engineering materials with a good specific strength. However, the effects of some process and geometrical parameters (such as fibre type, size, and concentration, and chemical modification) on the strength of the final natural composite product are not well documented. The purpose of the research is to analyse the physical and mechanical properties of single-strand buri palm fibre under different conditions and surface modification. The buri palm fibre was treated using 5 wt.% and 10 wt.% sodium hydroxide (NaOH) with a duration of 1 and 24 h immersion throughout the whole process. For a single-strand test, the samples were carefully extracted from the corresponding woven fibre by hand. While the woven buri palm fibre composite was fabricated by employing 4 and 5-layering sequences in the hand lay-up technique followed by the compression method. The buri palm fibre showed that a higher concentration of NaOH solution and immersion period led to a lower density. The effectiveness of the alkali treatment in the removal of cellulose and hemicellulose from the fibre strands was verified by chemical composition in FTIR investigation. The highest tensile strength of 159.16 MPa was indicated from the result of single-strand treated with 5 wt.% NaOH for 24 h immersion. This treatment was found as the most appropriate treatment and is employed to fabricate both 4-layer and 5-layer stacking sequence composite. The 5-layer treated composite gives the highest tensile strength and flexural strength of 33.51 MPa and 56.72 MPa, respectively. In conclusion, the mechanical properties increased with the addition of each sequence layering treated fibres in the composite. The obtained results indicate that the utilisation of buri palm fibre as a reinforcement in the epoxy composite can be used in the lightweight and moderate load applications, such as the interior parts in the automotive industry.

ARTICLE HISTORY
Received: 11th July 2020
Revised: 6th Oct 2020
Accepted: 24th Nov 2020

KEYWORDS
Corypha utan fibre;
Natural fibre;
Single-strand fibre;
Mechanical properties;
Alkaline

INTRODUCTION

Recent developments in natural fibre composite material have become one of the rapid growing attention in research and development due to environmental awareness and increase in synthetic materials price. Natural fibre reinforced polymer composites (NFRCs) has become a popular choice to substitute the synthetic reinforcing fibre because of abundance in availability, a renewable resource, economic, low density, biodegradable and have good specific properties [1-3]. Khan et al. [4] have shown that the NFRCs used in engineering applications such as in the automotive, aerospace, and construction industries. As reinforcement, it drives the natural fibre to be reused and recycled based on their specific mechanical properties. However, to be part of the application applied in engineering industries, it required specific performance terms of the mechanical properties and resistance to various to environmental condition and heat which in need of further investigation [5].

The significant increase in the research interest on the NFRCs in recent years has indicated that the NFRCs has become well known worldwide. This implied that NFRC research had been rapidly growing, while motivated by environmentally friendly issues [5-6]. Natural fibres such as flax, jute, kenaf, pineapple leaf, sisal, bamboo, and banana are renewable, recyclable, non-abrasive, and have a low safety risk. Nevertheless, the drawback of natural fibres includes lower modulus, low strength and hydrophilic as compared to synthetic fibres [7-8]. Most researchers who studied the mechanical properties of composite reinforced with short randomly oriented had used long-unidirectional fibres and woven fabric or mat [10]. Currently, there is a growing interest in using woven material in composite production for many applications since a woven or mat composite delivers superior mechanical properties [3, 9]. The design of woven fibre composite can be done with different stacking sequences, number of plies, and fibre orientation. The performance of varying fibre

*CORRESPONDING AUTHOR | J.P. Siregar | ✉ januar@ump.edu.my

layering sequences is different [12]. Rajesh and Pitchaimani [13] discovered a stacking sequence to affect the flexural strength of two different layers of jute fibre, whereby a four-layer jute fibre is higher than three-layer jute fibre composite. Rajesh et al. [14] studied the mechanical behaviour of woven natural fibre fabric composite, and indicated that a four-layer plain weave fibre gave the highest mechanical performance as compared to one-layer, two-layer, and three-layer jute fibre. A study by Sathishkumar et al. [15] found that the composite mechanical properties were increased by increasing the number of layers.

Generally, interfacial adhesion plays a role in transferring stress from matrix to fibre and determining the composite mechanical properties. The poor surface bonding between polymer matrix and fibre can be improved with a suitable chemical modification [8, 13]. Alkali treatment is one of the most common chemical treatments for natural fibre [17]. This treatment capable of increasing the surface roughness by removed a certain amount of cellulose, lignin, wax and oil content at the external fibre surface. The rough surface fibre is known to have better mechanical interlocking [13-15]. Alawar et al. [19] who analysed the characteristics of treated date palm tree fibre revealed that treatment with 1% concentration NaOH for 1 h at 100°C was the ideal treatment. Also, Zin et al. [9] reported that the tensile strength of a single-strand banana fibre increased with utilisation of alkaline treatment. The findings showed that the optimum concentration of alkali treatment is 6% NaOH for 2 h, which was capable of increasing 75% of tensile stress as compared to the untreated fibre. Zin et al. [9] also point towards, a higher NaOH concentration and longer immersion period would decrease the tensile strength.

To date, research on the buri palm fibre polymer composites is still rare. It was observed from the literature review, that no previous study was found on the properties of the single-strand buri palm fibre. There were also minimal studies in the literature on the effect of surface modification on the mechanical properties of buri palm fibre composite reinforcement. Besides, no integrated analysis of the sequence of fibre stacking and surface modification of the buri palm fibre composite found. These are the major gaps in the field of NFCs, which are interesting and challenging to work on. These are the major gaps in the field of NFCs, and it could be interesting as well as challenging to work on these research gaps. Therefore, in this research, the properties of single-strand buri palm fibre using two different concentration alkali treatments and immersion period have been characterised with respect to Fourier transformed infrared spectroscopy (FTIR), fibre density, physical analysis and mechanical properties. Furthermore, the highest tensile strength for single-strand fibre from the treatment was used for composite fabrication and the investigation of the effect of layering sequence of plain-woven buri palm fibre reinforced epoxy composites.

EXPERIMENTAL METHOD

Materials

The materials used in this study were plain-woven buri and epoxy resin. The matured buri leaf, which was used in this research was plain-woven and supplied by Pengrajin fibre, Jogjakarta Indonesia. The matrix used to fabricate the samples was Epoxy 816A with a density of 1.2 g/cm^3 and hardener epoxy 651, which were supplied by Impiana Z Enterprise (Malaysia). The epoxy resin system was provided by uniformly mixing the epoxy resin and hardener in a ratio of 3:1 by weight at room temperature. For alkalisation, a commercial grade of sodium hydroxide (NaOH) was used.

Samples Preparation

Alkaline treatment

The fibre was fully immersed in two different concentration which are 5 wt.% and 10 wt.% sodium hydroxide (NaOH), and two different immersion periods which are 1 h and 24 h at room temperature, and followed by washing with distilled water until the neutral (pH= 7) pH was obtained. Then, the fibres were dried in an oven at 105 °C for 24 h to get rid of the moisture. The process flow of alkali treatment of the buri palm fibre is illustrated in Figure 1. The NaOH concentration and immersion period are shown in Table 1. For a single-strand test, the samples were carefully extracted from the corresponding woven fibre by hand.

Laminates fabrication

The composite was prepared through a hand lay-up method followed by compression moulding to efficiently pull the epoxy resin into the layer of woven buri by removing the trapped air bubbles under 50 bar for 24 h at room temperature. Figure 2 shows the process flow of woven buri palm fibre composite fabrication. Four different configurations of buri palm fibre reinforced epoxy composites were fabricated by laminate configuration in Table 2.

Table 1. Buri palm fibre treatment using NaOH solution.

Sample	Immersion period (Hours)	NaOH %
Untreated	0	0
5 % - 1 h	1	5
10 % - 1 h	1	10
5 % - 24 h	24	5
10 % - 24 h	24	10

Table 2. Laminate configuration.

Sample	Laminate layering	Treatment
Untreated 4 ply	4	None
Untreated 5 ply	5	
Treated 4 ply	4	5 wt.% NaOH
Treated 5 ply	5	

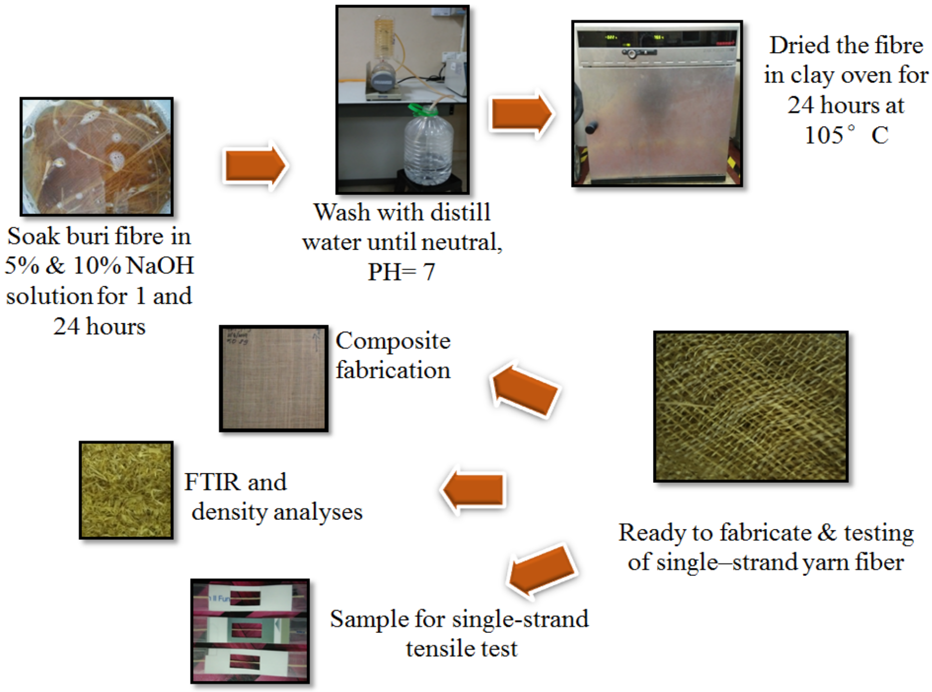


Figure 1. Process flow of alkali treatment of buri palm fibre.

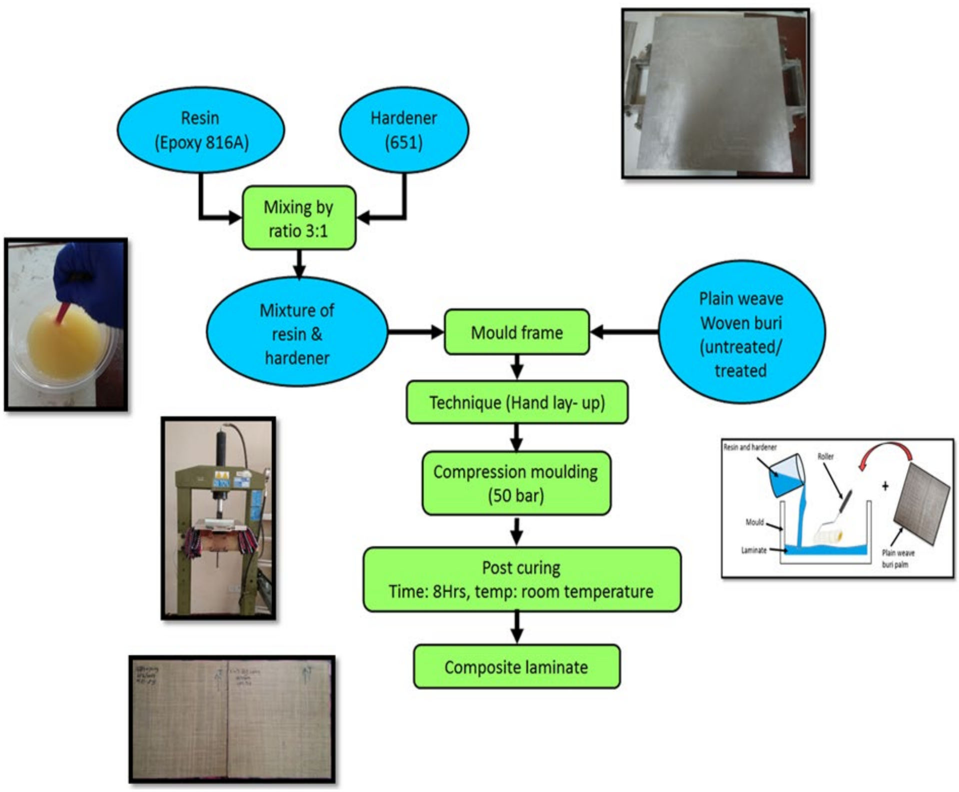


Figure 2. Process fabrication of woven buri palm fibre reinforced epoxy composites.

Each untreated and treated woven buri palm fibre composite consisted of four and five plies, as shown in Figure 3. The release agent was applied to the surface of an aluminium mould of dimension 300 × 300 mm for easy removal of the cured sample. The quality and performance of the composite product depend entirely on the fibre-matrix adhesion because it influences the stress transfer from matrix to fibre.

Fibre Characterisation

Fibre density

The density of the buri palm fibre was determined by electronic densimeter (MD 300S). The weight of the fibre before and after immersion was automatically calculated. The median of five buri palm fibre samples was recorded for different alkaline treatment concentrations and immersion periods.

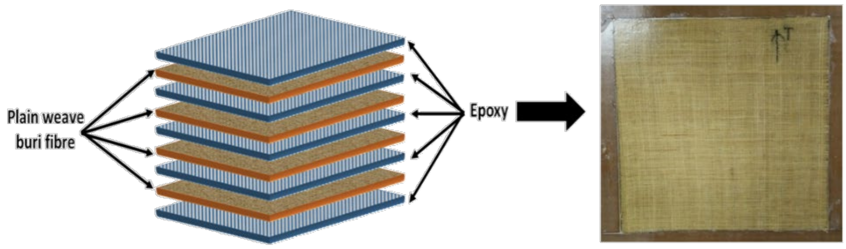


Figure 3. Staking sequence of woven buri fibre and epoxy composites.

Physical analysis

A Soptop optical microscopy at 2 times magnification was used to project and measure the diameter of a single-strand buri fibre. Since the buri fibre did not have a constant diameter, the diameter for each fibre strand was measured at three different points along the 25 mm fibre length and the mean value was taken. The physical appearance of buri fibre before and after alkaline treatment was observed under a microscope.

Fourier transform infrared spectroscopy (FTIR)

Fourier transformed infrared spectroscopy (FTIR) was performed by utilising a Perkin Elmer Spectrum 100 FTIR spectrometer and the standard KBr pellet technique. Buri palm fibre was finely ground and blended with KBr before being pressed into a pallet for measurement. A resolution setting of 4 cm^{-1} FTIR was prepared to analyse the possible chemical bonding that occurred in untreated and treated single- strand buri fibres. FTIR spectra were analysed over a frequency range of 400 cm^{-1} to 4000 cm^{-1} at room temperature. Each spectrum was scanned for four times prior to getting confirmation.

Mechanical Tests

Single strand tensile test

The single-strand fibre was manually separated from the plain-woven fibre. Tensile test for the untreated and treated buri fibre samples was conducted on the Instron 4505 according to ASTM C1557 at a speed of 2 mm/min. The samples were prepared at 25 mm in length and each test was repeated 30 times at room temperature. The average values were recorded. Figure 4 illustrates the single-strand of buri palm fibre that was attached to a paper holder with a heat shrink tape.

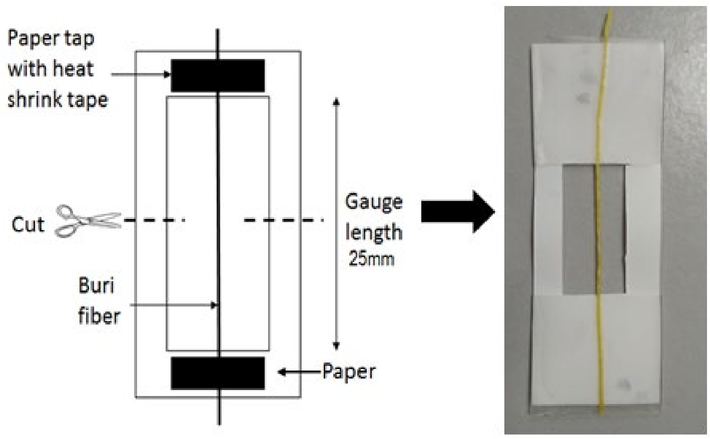


Figure 4. Buri strand fibre attached to a paper holder.

Tensile testing of composites

The tensile strength was conducted by using a standard universal testing machine, the 50 kN Instron-3369, according to the ASTM D638 procedure. The test speed was set at the 2 mm/ min and at room temperature. The load-displacement curves were obtained by Bluehill software, and the tensile strength and modulus values were calculated from the curves. For statistical purposes, five replicate specimens for each sample were tested, and the results were averaged.

Flexural test of composites

The three-point bending flexural test was carried out also by using 50 kN Instron universal testing machine according to the ASTM D790. The compression rate was set at 2 mm/ min, and the specimen span was set at 50 mm. The test was conducted within the elastic range of the material due to the limited number of sample. Five replicate samples of size 127 mm × 12.7 mm × 3 mm for each sample were tested, and the result values were averaged and analysed.

RESULTS AND DISCUSSION

Fibre Characterisation Analysis

Density of fibres

Density is the main gauge to design the lightweight composite structure and component. The density of the single-strand fibre, at different concentrations and immersion periods with alkaline treatment, are presented in Table 3. The results of the present study also showed that a higher NaOH solution concentration and immersion period led to lower density. As highlighted by Misnon et al. [20], the slight difference in density was due to the amount of cellulose in the fibre. Research findings by Wong et al. [21] also pointed out that the decrease in density of treated fibre could eliminate hemicelluloses, lignin, oils, waxes, and surface impurities by alkali treatment. The comparison result showed that higher cellulose content varies the high-density measurse. The above findings were found to be contradicted with the studies accomplished by Boopathi et al. [22] and Shanmugasundaram et al. [18], which examined the increase in alkali concentration which following the increase of the fibre density.

Table 3. Density of fibre for five series of measurement.

Fibre types	Series of measurement							
	1	2	3	4	5	Average	Stdv.	Std. error
Untreated	1.059	1.099	1.093	0.961	1.064	1.055	0.055	0.025
5 wt.%-1h	1.213	0.999	0.974	1.018	0.975	1.0358	0.101	0.045
10 wt.%- 1h	0.999	0.999	0.952	1.067	0.999	1.0032	0.041	0.018
5 wt.%- 24h	1.056	0.972	1.072	0.961	0.999	1.0120	0.050	0.022
10 wt.%- 24h	1.011	0.987	0.988	0.980	0.988	0.9908	0.012	0.005

Physical analysis of single-strand yarn

Diameter size of the same bundle had different readings. Figure 5 shows the typical optical microscopy image of the single-strand fibre cross-sectional area that was not circular and presented the diameter size along the fibre. To get the precise diameter measurement is challenging due to the varying size of the single-strand yarn [23]. It proved that the internal structure varies at different parts and in different plants [24].

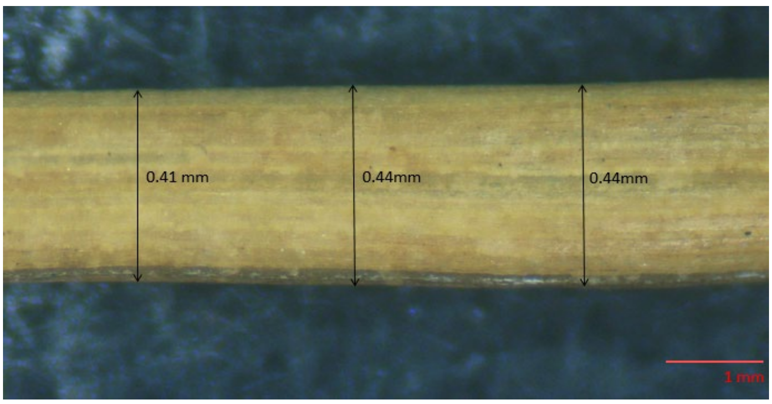


Figure 5. Image of the cross-sectional area and fibre width for single strand.

Through the chemical modification, alkalisation helps to make the natural fibre less hydrophilic due to the removal of a hydroxyl group from the fibre (Fibre – OH + NaOH → Fibre – ONa + H2O) [24]. Alkaline treatment affects surface modification. It can be investigated by the fibre diameter, which is the average for 30 samples for each condition, as shown in Table 4. It was apparent from this table that the average diameter showed a slight variation in value between the concentration and immersion period of NaOH. The fibre diameter showed a reduction for the increasing NaOH concentration and the immersion period. Vijay et al. observed a 27% reduction in the diameter of a tridax procumbens fibre as compared to untreated, which may be due to the removal of hemicellulose and lignin from the fibre's external surface [26]. The reduction of fibre diameter is because of the fibre morphology of treated fibre is change.

Table 4. Buri palm fibre treatment using NaOH solution.

Sample	Colour	Range of diameter (mm)
Untreated	Light brown	0.53 - 3.38 ± 0.01
5 % - 1 h	Bit darker	0.46 – 2.99 ± 0.01
10 % - 1 h		0.34 – 1.98 ± 0.01
5 % - 24 h	Much brighter	0.41 – 2.59 ± 0.01
10 % - 24 h		0.30 – 2.15 ± 0.01

The physical appearance of the buri fibre surface after treatment with different NaOH solution concentrations and immersion periods showed a slight colour change and is presented in Figure 6. Rokbi et al. [27] reported that the fibre colour became more yellowish when the percentage of NaOH solution and immersion period increased. This chemical modification helped to remove the wax and impurities from the fibre surface completely. It could be seen that the cleanliness and roughness of fibre surface increased by increasing the NaOH concentration and immersion period. Also, the high concentration of NaOH (10%) may damage the fibre surface, as seen in Figure 6(c) [1]. This is caused by the chemical structure on the fibre surface, which was modified by removing a certain amount of cellulose, lignin, hemicellulose, wax and oils. The result is verified by the FTIR investigation.

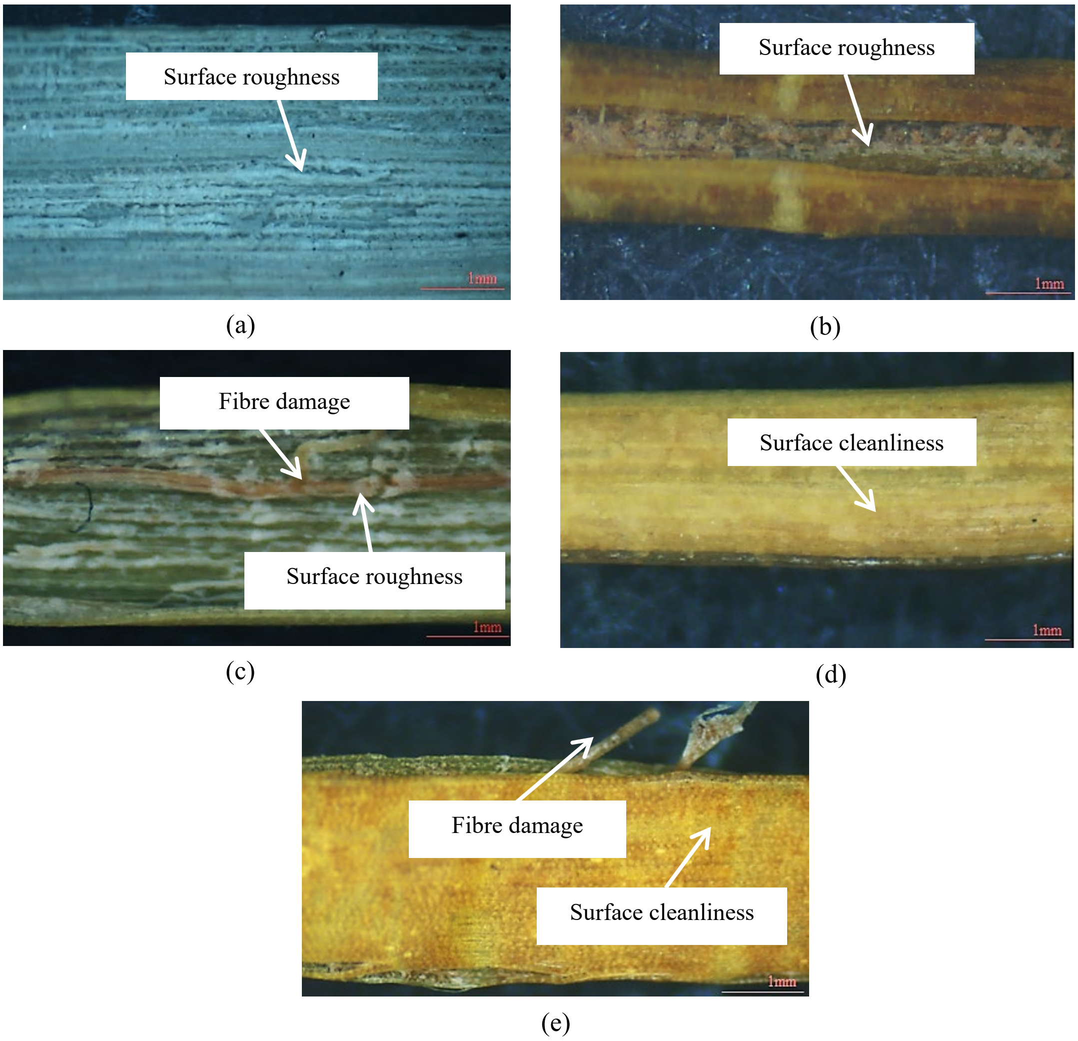


Figure 6. The physical appearance and effect of buri fibre after alkaline treatment under optical microscopy: (a) untreated strand fibre, (b) 5% NaOH solution 1 h immersion, (c) 10% NaOH solution 1 h immersion, (d) 5% NaOH solution 24 h immersion, (e) 10% NaOH solution 24 h immersion.

Analysis of Fourier transform infrared spectroscopy (FTIR)

FTIR spectra of untreated and treated buri palm fibre are displayed in Figure 7. The intense peak in the region between 3000 cm^{-1} and 3500 cm^{-1} corresponded to the OH stretching vibration and the hydrogen bonding of the hydroxyl groups. The OH compounds may be related due to the presence of carbohydrate (cellulose and hemicellulose) and hydroxyl groups [24-25]. The concentrations and immersion periods of NaOH for the fibres were nearly the same. The sample test pieces were examined and the peak position of IR bands was recorded and can be summarised and compared in Table 5, as extracted from Figure 7.

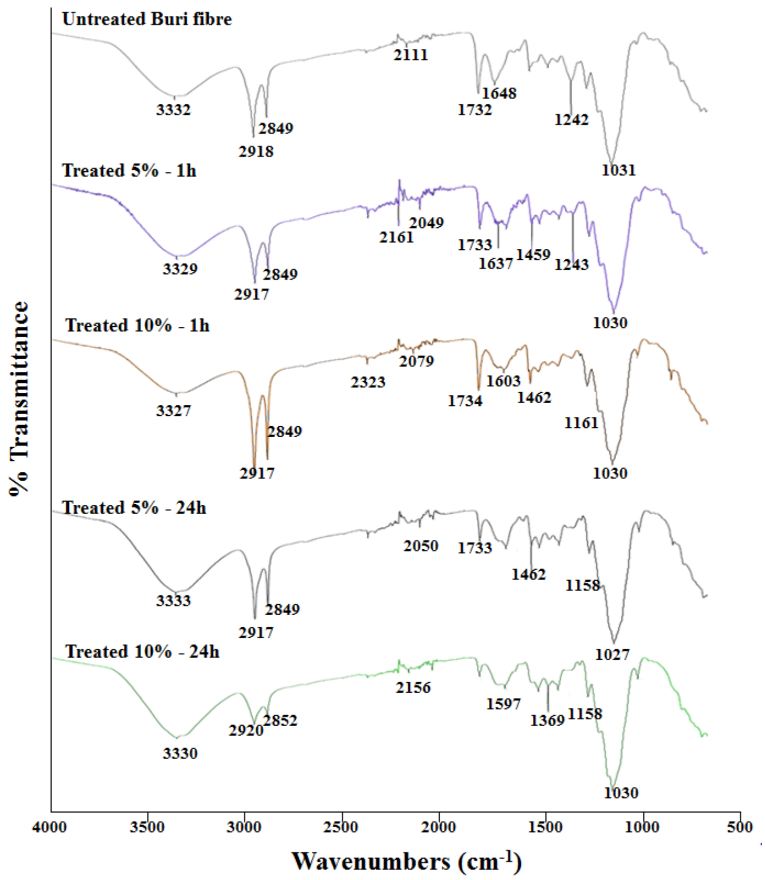


Figure 7. FTIR untreated buri fibre and treated spectrum of 5% - 1 h, 5% - 24 h, 10% - 1 h and 10% - 24 h.

The peak of untreated fibre was observed at 3332 cm^{-1}. Meanwhile for the 5% -1h, 10% -1h, 5%- 24 h, and 10%- 24 h treatments, the peak was 3329 cm^{-1}, 3327 cm^{-1}, 3333 cm^{-1} and 3330 cm^{-1}, respectively. It showed that the treated buri fibre had a higher absorbancy at 1 h 5% NaOH in O-H stretching. The peak at 2900 cm-1 and 2855 cm-1 of the vibration was probably associated with the CH stretching of cellulose fibre [29-30]. The FTIR results indicated that certain chemical reactions during the alkali treatment of the single-strand fibres at peak around 1595- 1980 cm^{-1} were due to C=C stretching bond of the aromatic rings of lignin. Another peak indicated at 1243- 1462 cm^{-1} was responsible for CH_2 symmetric bonding.

Mechanical Properties

Single-strand tensile properties

The effects of untreated and alkaline treated single-strand buri fibre with different concentrations and immersion periods on tensile properties performance were presented in Figure 8. It was observed that there was an improvement in the tensile strength of buri fibre with 5 wt.% and 10 wt.% NaOH with 1 h and 24 h immersion period. The maximum tensile strength showed at 5% NaOH for 24 h immersion period, 159.16 MPa. An increase of 86.54% was significantly found as compared to the untreated fibre. The result showed that the higher tensile strength of the lower concentration of NaOH with the same immersion period, while for 5 wt.% and 10 wt.% for 1 h immersion were 99.18 MPa and 90.60 MPa, which was an increase of 16.24% and 6.19% compared to untreated fibre. Therefore, the results of this section found clear support for further composite fabricated to study the effect of buri palm fibre treatment and stacking sequence.

Table 5. Bonds wavenumber related to regions untreated and treated buri fibre.

Bond functional group	Untreated buri fibre	5%-1 h	10% -1 h	5% -24 h	10% -24 h
	Wavenumber (Cm^{-1})				
OH stretching – Alcohol, water, phenol	3332	3329	3327	3333	3330
C-H stretching O-H stretching- Alkanes (CH; CH_2; CH_3), Carboxylic acids	2918, 2849	2917, 2849	2917, 2849	2917, 2849	2920, 2852
C=C aromatic symmetrical stretching – Nitriles, Alkynes	2111	2323	2323	2323,	2105
C=C stretching – Alkenes (Lignin)	1732, 1648	1979, 1594	1734, 1603	1980, 1595	1980, 1597
C-H bending – Alkanes (cellulose, hemicellulose, lignin)	1462	1459	1462	1462	1420
C-O stretching – Alcohol (cellulose; hemi- cellulose; lignin) Carboxylic Acids, Esters, Ethers	1161	1159	1161	1158	1158
COC, CCO and CCH deformation and stretching	-	-	897	897	897

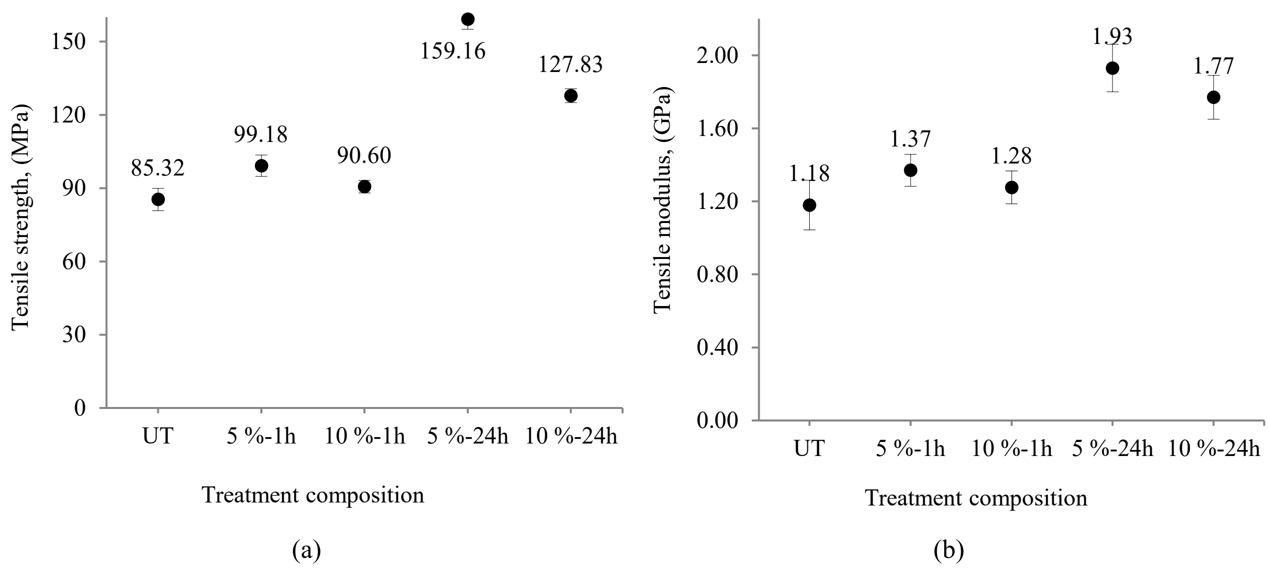


Figure 8. (a) Tensile strength and (b) tensile modulus of single-strand buri fibre untreated and alkaline treatment.

This finding was consistent with discoveries of past studies by Hossain et al. [23], in which the single strand sugarcane fibre treated with 5 wt.% alkali solution for 24 h showed the maximum tensile strength. This may cause the alkali reaction on the fibre to remove the fibre constituents, such as hemicellulose, wax, lignin, and pectin to improve the fibre wettability and interfacial strength [19, 27]. The right and ideal treatment can accomplish better and stronger composites [32]. Boopathi et al. [22] investigated the behaviour of borassus fruit fibres treated with different NaOH concentrations for 0.5 h at room temperature and found that the 5 wt.% alkali-treated condition had improved tensile strength as compared to the other 10 wt.% and 15 wt.% concentrations. Venkatachalam et al. [33] also reported that the 5 wt.% NaOH-treated fibre reinforced polyester composite had better tensile strength as compared to the 10 wt.% NaOH-treated fibre composite. This delignification of natural fibre cans harm the fibre surface at high NaOH concentration. These results contradicted the experimental findings of Kabir [16], who considered that treated hemp fibres exhibited lower tensile stress as compared to untreated fibres. The result indicated that higher NaOH concentrations (6-10 wt.%) increased the tensile strength because higher concentrations effectively removed lignin and hemicellulose, which were covering fibre surface.

Tensile test of composite

The tensile strength and modulus of composites with different layering sequence of untreated and treated buri fibres are compared in Figure 9. Basically, two types of layering sequence were evaluated in the present study, which was a 4-layer and 5-layer laminate with almost similar fibre content. The sample with 4-layer untreated (UT4) laminate exhibited an average value of tensile strength which was 20.88 MPa. Meanwhile, the average value for the sample 5-layer untreated (UT5) woven fibre was 25.44 MPa. The tensile strengths of the 4-layer (T4) and 5-layer (T5) treated laminate were discovered at 31.23 and 33.51 MPa, respectively.

The tensile strength of alkali-treated fibre reinforced composite with the 4-layer laminate showed an increase of 49.57% while the treated reinforced composite with a 5-layer laminate showed an increase of 31.72%. These may be caused by the rougher surface of treated buri fibre as well as removed impurities, shown in Figure 10(a). The tensile strength of untreated buri fibre composite with a 4-layer stacking sequence was lower than the untreated with five layers (21.84%). It may be because of the lignin and hemicellulose which were present on the fibre, and thus the fibril in the fibre could be easily pulled out, as depicted in Figure 10(b). Sathishkumar et al. [34] mentioned that fibre pull-out happened because of interfacial bonding need at the fibre and matrix interphase. Figure 10(c) exhibited the tensile fractured at treated fibre composite with 4-layer stacking sequence. Strength at the interface of fibre and epoxy matrix was higher due to individually fibre breakage. According to Mahjoub [1] and Adenkule [35], alkali treatment improved different fibre surface interfacial bonds between the matrix and fibre surface due to the removal of lignin and hemicellulose. Therefore, better mechanical properties would have resulted in the polymer composite. In contrast, a study by Sepe and friends [36] indicated that the lowest tensile strength was acquired in the composite hemp fibre reinforced epoxy with 5% NaOH concentration as compared to the untreated with 1% NaOH concentration.

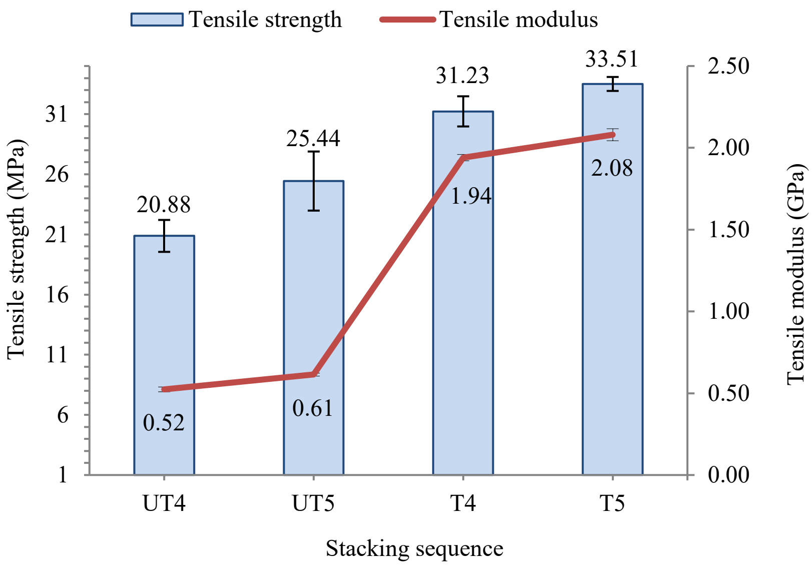
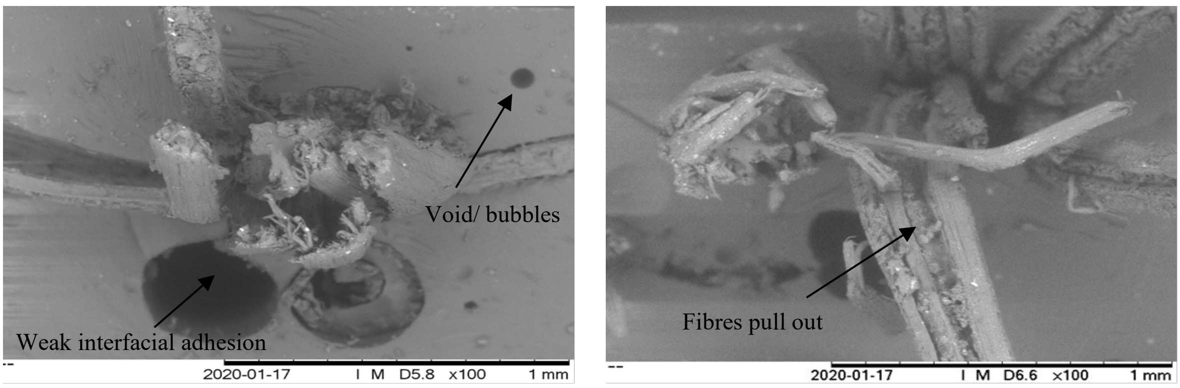
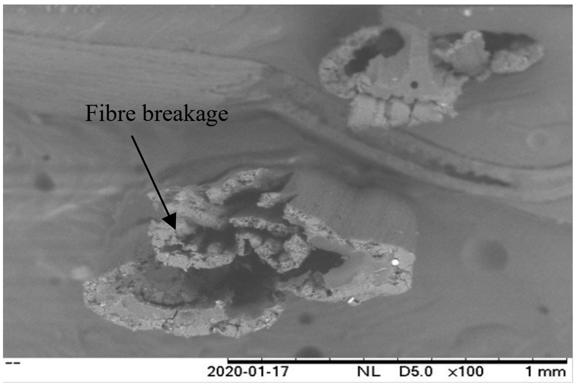


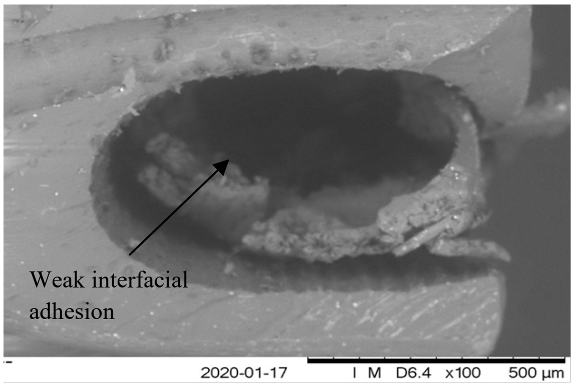
Figure 9. Tensile strength and tensile modulus of untreated and treated buri fibre stacking sequence composites.



(a) (b)



(c)



(d)

Figure 10. Tensile fracture specimen under SEM micrographs for (a) UT 4, (b) UT 5, (c) T4, and (d) T5.

Flexural test of composite

Flexural strength defines the capability of the laminate composite to withstand the bending before the breaking point is reached. Result for flexural strength and flexural modulus of untreated and treated buri fibre reinforced epoxy composites are plotted in Figure 11. The flexural strength properties of untreated or treated buri fibre were found to increase with an increase in the layer. The most noteworthy flexural strength of composite laminate was observed in the 5-layer NaOH-treated due to strong surface roughness and good interfacial bonding among fibre and matrix. The flexural strengths of untreated and treated buri fibre reinforced epoxy composites with 4-layer stacking arrangement were nearly the same, which were 42.33 MPa and 42.51 MPa, respectively. Otherwise, the increment percentage in flexural strength of the treated buri fibre reinforced epoxy composite with a 5-layer stacking sequence was 24.39% as compared to the untreated fibre. The maximum modulus of 2.56 GPa was achieved with 5-layer stacking sequence treated fibre. This investigation discovered that generally flexural properties were expanded with an increase in woven buri fibre layer. According to Arthanarieswaran et al. [37], this was mainly due to the load transfer capability of the laminated composite, which was the compressive load at the upper layer. Moreover, the tensile stress at the lowest and intermediate layers was a shearing force and not uniform along the length when there was an increase in the number of layers.

The flexural modulus of the composite materials increased with the increase in layering sequence and alkali treatment. The specimens T5 evidenced the highest flexural modulus of 2.56 GPa. The UT4 buri palm fibre reinforced epoxy composites showed the lowest flexural modulus, 2.33 GPa. On the other hand, the flexural modulus of buri palm fibre reinforced epoxy composites was improved from 4.29% to 8.02% when the buri palm fibre was treated with 5 wt.% NaOH.

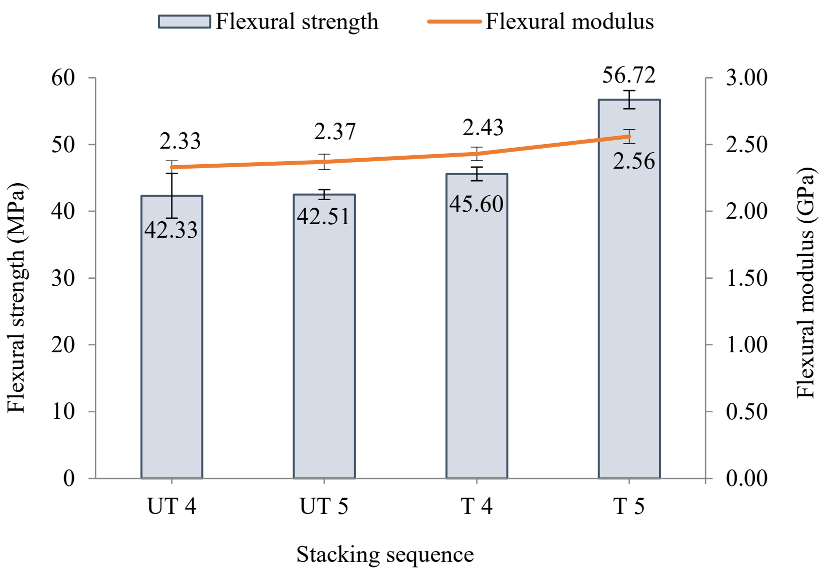


Figure 11. Flexural strength and flexural modulus of untreated and treated buri fibre stacking sequence composites.

CONCLUSION

This paper proposed the various properties of single-strand buri palm a fibre that was studied using different concentration of alkali treatment and immersion period. It was found that:

i. The single-strand fibre tensile properties showed that with the alkali treatment for 24 h immersion period, the tensile strength had been improved to 159.16 MPa (5%) and 127.83 MPa (10%) from 85.32 MPa (untreated fibre). This surface roughness enhancement was due to the removal of hemicellulose, lignin, and wax contents. Among the acceptable explanations for these findings were that alkaline treatment with 5% NaOH concentration and 24 h immersion period could be a possible treatment to be applied on the natural fibre before it is employed as the reinforcement in the polymer composite.
ii. The alkali treatment has decreased the density and diameter of the fibre since it removed wax, lignin, hemicellulose, and cellulose from the surface.
iii. The woven buri palm fibre reinforced epoxy composite with 5-layer treated fibre had the best tensile strength and flexural strength of 33.51 MPa and 56.72 MPa, respectively.
iv. The tensile strength and flexural strength of the composite was increased tremendously with the addition of each woven fibre layer stacking sequence.

These findings have enhanced our understanding of the evaluated surface fibre and mechanical properties which were significantly affected by the alkali treatment of the buri fibres. The result of this study indicated that buri palm fibre reinforced epoxy composite can be used in the lightweight and moderate load applications, such as the interior parts in the automotive industry.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Education Malaysia for providing the Hadiah Latihan Persekutuan 2018 Scheme: HLP scholarship for the research funding. This research work was strongly supported by the Structural Materials & Degradation Focus Group (SMD), Universiti Malaysia Pahang, which provided the research materials and equipment.

REFERENCES

[1] Mahjoub R, Mohamad J, Rahman A, et al. Tensile properties of kenaf fiber due to various conditions of chemical fiber surface modifications. Construction and Building Materials 2014; 55: 103–113.

[2] Prasad GLE, Megha BE, Gowda BSK. Study of mechanical characteristics of banana and jute fiber reinforced polyester composites. In: Thakre P, Singh R, Slipher G, editors. Mechanics of Composite, Hybrid and Multifunctional Materials, Volume 5. Springer International Publishing, 2019, p 23–29.

[3] Rong SY, Mubarak NM, Tanjung FA. Structure-property relationship of cellulose nanowhiskers reinforced chitosan biocomposite films. Journal of Environmental Chemical Engineering 2017; 5: 6132–6136.

[4] Khan MZ, Srivastava SK, Gupta M. Tensile and flexural properties of natural fiber reinforced polymer composites : A review. Journal of Reinforced Plastics and Composites 2018; 1: 1–21.

[5] Kandola BK, Mistik SI, Pornwannachai W, et al. Natural fi bre-reinforced thermoplastic composites from woven-nonwoven textile preforms : Mechanical and fire performance study. Composites Part B 2018; 153: 456–464.

[6] Hao LC, Sapuan SM, Hassan MR, et al. Natural fiber reinforced vinyl polymer composites. Journal of Mechanical Engineering and Sciences 2018; 27–70.

[7] Dong C. Review of natural fibre-reinforced hybrid composites. Journal of Reinforced Plastics and Composites 2017; 1–18.

[8] Zamri MH, Md Akil H, Abu Bakar A, et al. Effect of water absorption on pultruded jute/ glass fiber-reinforced unsaturated polyester hybrid composites. Journal of Composite Materials 2011; 1: 1–11.

[9] Zamri MH, Md Akil H, Abu Bakar A, Mohd Ishak ZA, Cheng LW. The effects of alkali treatment on the mechanical and chemical properties of banana fibre and adhesion to epoxy resin. In: IOP Conference Series: Materials Science and Engineering, pp. 161–176; 2018.

[10] Hamdan MHM, Siregar JP, Ahmad MR, et al. Characterisation of the woven fabric of jute, ramie and roselle for reinforcement material for polymer composite. Materials Today: Proceedings. Epub ahead of print 2020. DOI: 10.1016/j.matpr.2020.07.372.

[11] Aisyah Humaira A, Paridah MT, Khalina A, et al. Evaluation of kenaf yarn properties as affected by different linear densities for woven fabric laminated composite production. Sains Malaysiana 2018; 47(8): 1853–1860.

[12] Siregar JP, Zalinawati M, Cionita T, et al. Mechanical properties of hybrid sugar palm / ramie fibre reinforced epoxy composites. Materials Today: Proceedings. Epub ahead of print 2020. DOI: 10.1016/j.matpr.2020.07.565.

[13] Rajesh M, Pitchaimani J. Mechanical properties of natural fiber braided yarn woven composite : Comparison with conventional yarn woven composite. Journal of Bionic Engineering 2017; 14: 141–150.

[14] Rajesh M, Singh SP, Pitchaimani J. Mechanical behavior of woven natural fiber fabric composites : Effect of weaving architecture , intra-ply hybridisation and stacking sequence of fabrics. Journal of Industrial Textiles 2016; 2: 1–22.

[15] Sathishkumar TP, Naveen J, Navaneethakrishnan P, et al. Characterisation of sisal/ cotton fibre woven mat reinforced polymer hybrid composites. Journal of Industrial Textiles 2016; 47(4), 429-452.

[16] Kabir MM, Wang H, Lau K., et al. Tensile properties of chemically treated hemp fibres as reinforcement for composites. Composites Part B 2013; 53: 362–368.

[17] Faisal ZHT, Amri F, Salmah H, et al. The effect of acetic acid on properties of coconut shell filled low density polyethylene composites 2010; 10: 334–340.

[18] Shanmugasundaram N, Rajendran I, Ramkumar T. Characterization of untreated and alkali treated new cellulosic fiber from an Areca palm leaf stalk as potential reinforcement in polymer composites. Carbohydrate Polymers 2018; 195: 566–575.

[19] Alawar A, Hamed AM, Al-kaabi K. Characterization of treated date palm tree fiber as composite reinforcement. Composites Part B 2009; 40: 601–606.

[20] Misnon MI, Islam MM, Epaarachchi JA, et al. Analyses of woven hemp fabric characteristics for composite reinforcement. Materials and Design 2014; 66: 82–92.

[21] Wong K, Yousif BF, Low KO. The effects of alkali treatment on the interfacial adhesion of bamboo fibres. Journal of Material Design and Application 2010; 224: 139–148.

[22] Boopathi L, Sampath PS, Mylsamy K. Investigation of physical , chemical and mechanical properties of raw and alkali treated Borassus fruit fiber. Composites Part B 2012; 43: 3044–3052.

[23] Hossain MK, Karim MR, Chowdhury MR, et al. Comparative mechanical and thermal study of chemically treated and untreated single sugarcane fiber bundle. Industrial Crops & Products 2014; 58: 78–90.

[24] Osman E, Vakhguelt A, Mutasher S, et al. Effect of water absorption on tensile properties of kenaf fiber unsaturated. Journal of Science Technology 2013; 20: 183–195.

[25] Jawaid M, Abdul Khalil HPS. Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. Carbohydrate Polymers 2011; 86: 1–18.

[26] Vijay R, Singaravelu DL, Vinod A, et al. Macromolecules characterization of raw and alkali treated new natural cellulosic fibers from tridax procumbens. International Journal of Biological Macromolecules 2019; 125: 99–108.

[27] Rokbi M, Osmani H, Imad A, et al. Effect of chemical treatment on flexure properties of natural fiber-reinforced polyester composite. Procedia Engineering 2011; 10: 2092–2097.

[28] Fan M, Dai D, Biao H. Fourier transform infrared spectroscopy for natural fibres. In: Mohammed Salih S, editor. Fourier Transform- Materials Analysis, London: IntechOpen, 2012, p 45–68.

[29] Nadlene R, Sapuan SM, Jawaid M, et al. The effects of chemical treatment on the structural and thermal , physical , and mechanical and morphological properties of roselle fiber-reinforced vinyl ester composites. Polymer Composites 2018; 39(1): 274-287.

[30] Ramesh M. Kenaf (Hibiscus cannabinus L .) fibre based bio-materials : A review on processing and properties. Journal of Progress in Materials Science 2016; 78–79: 1–92.

[31] Pickering KL, Efendy MGA, Le TM. A review of recent developments in natural fibre composites and their mechanical performance. Composites Part A 2016; 83: 98–112.

[32] Ticoalu A, Aravinthan T, Cardona F. A review of current development in natural fiber composites for structural and infrastructure applications. In: Southern Region Engineering Conference, Toowoomba, Australia, pp. 1–5; 2010.

[33] Venkatachalam N, Navaneethakrishnan P, Rajsekar R, et al. effect of pretreatment methods on properties of natural fiber composites: A review. Polymers and Polymer Composites 2016; 24: 555–566.

[34] Sathishkumar TP, Navaneethakrishnan P, Shankar S. Tensile and flexural properties of snake grass natural fiber reinforced isophthallic polyester composites. Composites Science and Technology 2012; 72: 1183–1190.

[35] Adekunle KF. Surface treatments of natural fibres — A review : Part 1. Open Journal of Polymer Chemistry 2015; 5: 41-46.

[36] Sepe R, Bollino F, Boccarusso L, et al. Influence of chemical treatments on mechanical properties of hemp fiber reinforced composites. Composites Part B 2018; 133: 210–217.

[37] Arthanarieswaran VP, Kumaravel A, Kathirselvam M. Evaluation of mechanical properties of banana and sisal fiber reinforced epoxy composites : Influence of glass fiber hybridisation. Journal of Materials and Design 2014; 64: 194–202.