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Improving the Properties of Kenaf Bast Fibre Acrylonitrile Butadiene Styrene (ABS) Composite via a new Surface Treatment Technique

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ABSTRACT

The low mechanical properties of natural fibre composites have limited their use in engineering applications, paving ways for synthetic fibres that are ecologically non-sustainable. This study is targeted at finding suitable and acceptable industrial application of kenaf natural fibres in engineering solutions via a new treatment method. Kenaf bast fibre reinforced ABS composites were developed with the purpose of reducing intrinsic high moisture absorption and improving fibre–matrix interface. Treatment of the fibres were done with sodium hydroxide solution, then coated with thermosetting epoxy resin before composite fabrication. The treated and coated kenaf fibre (ENKF), coated kenaf fibre (EKF) and natural kenaf fibre (KF) fibres were incorporated into ABS at 10 wt% constant fibre loading. Melt-mixing was done using twin-screw extruder before compression moulding at a temperature of 240 °C, pressure of 65 kg/m^2 for 5 minutes. FTIR and SEM analyses were conducted on the untreated, treated and coated fibres. Mechanical properties such as three-point bending, impact, and tensile properties of the constituent ENKF/ABS, EKF/ABS and KF/ABS composites and the fracture properties were also studied with varying fibre loadings of up to 15 wt%. The results show that the coating was effective in reducing the peaks intensity for the FTIR analysis, all the properties of kenaf/ABS composites were better improved by the new surface coating treatment with epoxy resin than the NaOH treated composites with EKF/ABS composites having superior properties than ENKF/ABS composites. Both were better than KF/ABS that exhibited poor interfacial bonding leading to lower mechanical properties. The mechanical properties of the composites recorded an increase in value with increasing fibre loading up to 15 wt%. FESEM studies of EKF/ABS and ENKF/ABS revealed the absence of debonding and delamination due to coating. Kenaf natural fibre composite properties can thus be improved further by coating, finding increased applications in industrial productions.

Keywords: *Kenaf fibres; epoxy coating; engineering thermoplastics; ABS composites*

1. Introduction

An important and determining factor in making a choice for application areas of different industrial products is the mechanical property (Tezara *et al.*, 2016). When compared with other natural fibres, kenaf plant fibre is one of the fibres with high mechanical properties and is suitable for wide range of extruded, moulded and non-woven products (Edeerozey *et al.*, 2007). They have drawn the interests of many researchers and have replaced glass fibres as reinforcement in most polymer composites owing to their great advantages such as low cost, recyclability, density, renewability, abrasiveness, environmentally friendly and biodegradability (Razak *et al.*, 2014). The main challenge in their utilisation in plastic manufacturing is their degradation at high processing temperatures, compatibility problem between hydrophobic polymer matrix and the hydrophilic fibres; the intrinsic high moisture absorption resulting in microcracking, dimensional changes of the fibres and reduced mechanical strength of the composites (Asumani *et al.*, 2012; Akil *et al.*, 2011; Srinivasan *et al.*, 2014).

Different chemical treatment such as silane treatment, alkali treatment, reactive additives and coupling agents etc., have been employed to modify the surface of the fibre for effective interfacial bonding between matrix and the fibre. These treatments have been found to aid efficient coupling with the matrix by exposing more reactive groups on the fibre surface thereby resulting to better thermal, mechanical and performance properties of the composites (VijayaRamnath *et al.*, 2013; Abdelmouleh *et al.*, 2007; Girisha *et al.*, 2012; Corradini *et al.*, 2009; Dehghani *et al.*, 2013; Tezara *et al.*, 2016). Obtaining alternative method for the improvement of fibre interfaces with polymer matrix is very necessary and forms the backbone of this work.

The use of epoxy resins as coating agent in this work is drawn from the fact that it is a very good thermoset which have found wide applications in composites as matrix resin, adhesives and coatings (Thitithanasarn *et al.*, 2012). Their desirable properties such as good thermal properties, chemical resistance and dimensional stability are related to the degree of cross linking or cross link density (Saliu *et al.*, 2015a; Loos *et al.*, 2008; OzerenOzgul and Ozkul, 2018). This is possible because epoxy resin coating is able to penetrate the micropores on the fibre surfaces acting as coupling agent; this behaviour develops mechanically interlocked coatings on the fibre surface. But, despite these successes, extensive report has not been made in coating natural fibres as a treatment method.

The aim of this work is to produce kenaf bast fibre reinforced thermoplastic (ABS) composites using the new treatment (epoxy-coating) technique in comparison with conventional alkali treatment method. The effectiveness of the surface coating and chemical treatment as well as the fibre loadings of the resultant composites will be studied.

2. Experimental

2.1 Materials

A commercial grade of ABS polymer chips supplied by Toray Plastics Malaysia Sdn. Bnd was used as the matrix. The kenaf fibres used as fillers were provided by the Agricultural Research and Development Institute (MARDI) of Malaysia. Epoxy resin/hardener and Acetone (C_3H_6O) used for the coating were provided by Oriental Option Sdn. Bhd and SYSTERM respectively. Analytical grades of acetic acid (CH_3COOH) and sodium hydroxide (MERCK) were employed for the treatment of the fibres.

2.2 Fibre surface treatments and Coating

As a way of improving compatibility of ABS with the fibre and reduction of moisture absorption properties, the kenaf fibres were subjected to surface treatment with NaOH and epoxy resin coating. Treatment of the kenaf fibres was for 3 hours using 6% NaOH, neutralization with 100% acetic acid before rinsing with distilled water until neutral pH was obtained. The fibres were finally dried for 12 hours at an oven temperature of 70 °C.

Epoxy resin and hardener mixed in the ratio of 2:1 was used for the coating of raw kenaf fibres (KF) and NaOH-treated fibres (NKF). Acetone was used to dissolve the epoxy using epoxy to acetone ratio of 1:5. The raw kenaf (KF) and alkali (NKF) treated fibres were immersed in the thinned epoxy solution for a period of 3 minutes contact time. The kenaf fibres were chopped into short 5 mm mesh sizes followed by curing of the treated and coated fibres at a temperature of 80 °C for 24 hours in an oven.

2.3 Composites Preparation

The composite preparations were done in two stages: at the first stage, the constituent materials KF/ABS, EKF/ABS and ENKF/ABS were compounded at constant fibre loading of 10 wt % to determine the outcome of chemical treatment and coating. At the second stage, in order to determine the effect of kenaf fibre loading, only ENKF/ABS constituent was compounded at different fibre loadings of 5 wt %, 10 wt % and 15 wt %. Twin-screw extruder was employed for the compounding of the entire constituent materials at an optimized screw speed and processing temperature of 50 rpm and 240 °C respectively.

The extrudates (melt-mixed) which were pelletized was then compression moulded into sheets after drying in an oven for 3 hours at 80 °C. The compression moulding temperature of 240 °C was maintained at constant pressure and time of 65 kg/m^2 and 5 minutes respectively. Preheating, hot pressing and cold pressing times were 2 minutes, 3 minutes and 5 minutes (cooled at 25 °C) respectively. The composites were characterized mechanically and morphologically.

2.4 Fibre Characterization (FTIR and SEM)

The raw and coated kenaf fibres were subjected to FTIR spectroscopic analysis using FTIR spectrometer (Perkin Elmer Spectrum 400, model. Perkin Elmer Inc., USA) to examine possible changes in chemical structure and functional groups. This was done over a spectra range of 4000 cm^{-1} to 1000 cm^{-1}.

To investigate changes on surface properties and structural constituents due to the treatment and epoxy coating effects, SEM analysis was carried out with Hitachi Scanning Electron Microscope at an accelerating voltage of 5–20 kV.

2.5 Composites characterization (Tensile, flexural and Impact Strength)

Universal Tester (Model AG-X Series, Japan) was used for the analyses of the tensile (ASTM D 638) and flexural (ASTM 790) samples at standard testing conditions of 24 °C and 50% temperature and relative humidity respectively. An average of five specimens was used per sample for the test using a crosshead speed of 5 mm/min and 2 mm/min for the tensile and flexural tests respectively (Figure 1).

Measurement of impact properties was carried out using INSTRON dynatup impact tester based on ISO 180 standards testing methods. Sudden loads were applied to the samples to test their strengths and an average of five specimens per sample was analysed.

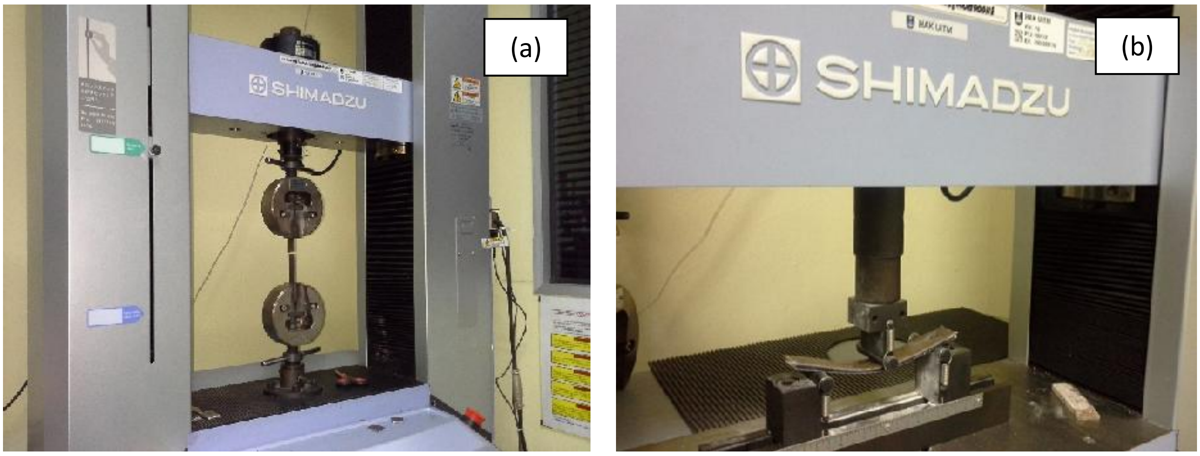

Figure 1: (a) Tensile testing procedure showing the test specimen clamped in the SHIMADZU Universal Tester and (b) Flexural testing procedure showing the 3-point bending configuration.

2.6 Morphological analysis (FESEM)

The study of fractured surfaces of both the treated and coated kenaf composites was performed with Field emission scanning electron microscopy (ZEISS FE-SEM Germany) SUPRA 40VP Model for different magnifications. Sputter-coating was done to make the samples more conductive, using thin layer of platinum on a coating machine (Quorum model Q150RS, UK). The positioning of the samples was at 30 ° for better viewing.

3. RESULTS AND DISCUSSION

3.1 FTIR Analysis

To reduce moisture absorption and improve the surface area, fibre surface treatment and coating were carried out on the fibre and characterised. The superimposition of FTIR spectra for natural kenaf fibre (KF), NaOH treated (NKF) and epoxy coated-treated (ENKF) are displayed in Figure 2a

The vibration peak intensities of natural kenaf fibres (KF) were found at 1028 - 1750 cm^{-1} which revealed the presence of lignin, cellulose and hemicelluloses with their broad bands which was also mentioned by Asim *et al.* (2016). The absorption peaks at 2910 cm^{-1} are associated with the C-H stretching vibration of CH_2 groups in hemicelluloses and cellulose. The presence of hydroxyl –OH group can also be found at 3336 cm^{-1} in the kenaf fibre.

The spectrum of surface treated and coated kenaf fibre (EKF) in Figures 2a and 2b respectively show a significant reductions in peak intensities, an indication of improved fibre surface with respect to natural kenaf fibres as a result of treatment and epoxy coating. The result means that surface treatment and coating has helped in reducing the hydrophilicity and water intake characteristics of the fibre without adversely affecting the fibre's chemical composition. The C=C stretch absorption band belonging to the ester carbonyl group occurred at 1730 cm^{-1} showing that an ester chain was formed between the hydroxyl group contained in the fibre and the epoxy resin coated fibre (Razak *et al.*, 2014). This is not found in the fibre treated with NaOH. The absorption due to epoxy group (at 3336 cm^{-1}) was absent for the NaOH treated samples, and also in the natural kenaf fibre. This absorption peak is the location of cross-linking for the hydroxyl group and the epoxy coated fibres. The epoxy resin and the cellulosic hydroxyl group in the fibre interacted well leading to the missing peaks at 1730 cm^{-1} and 2910 cm^{-1}. C-H stretching band is responsible for another peak at 2910 cm^{-1}. Asim *et al.* (2016) also reported the presence of vibrational peak between 3336 cm^{-1} and 3400 cm^{-1} indicating a frequency due to O-H group. It was also observed that NaOH treated kenaf fibre (NKF) showed similar spectrum as epoxy-coated kenaf fibres (EKF) which revealed low peak intensity and its effect on lignin and hemicelluloses, an indication of successful treatment. Wax content, hemicelluloses and lignin have been effectively removed making the absorption peak at 3336 cm^{-1} to be broader when compared to the untreated fibre. Large amount of the hydroxyl groups found in the kenaf fibre have been covered by the epoxy resin after coating (Figure 2b).

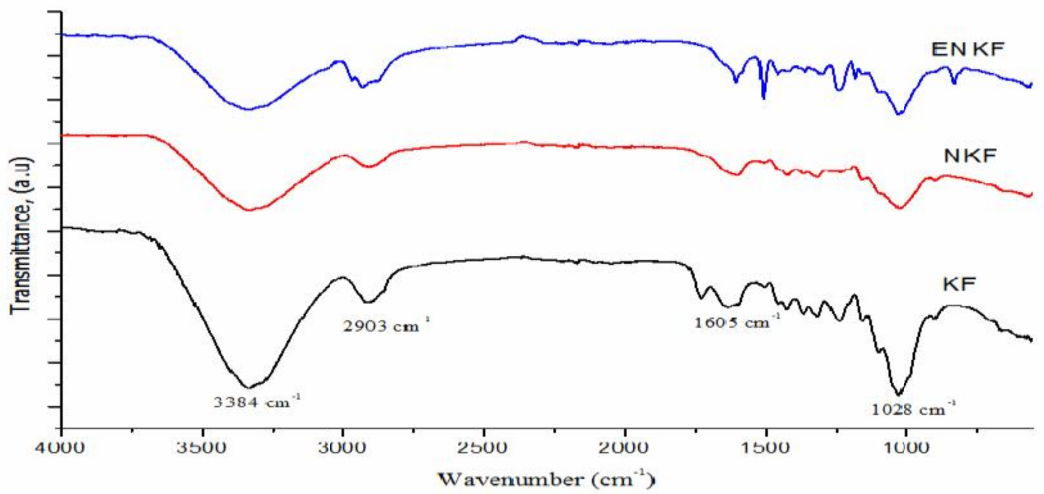

Figure 2a: The Spectra of raw kenaf (KF), NaOH-treated kenaf (NKF) and epoxy coated-treated kenaf (ENKF)

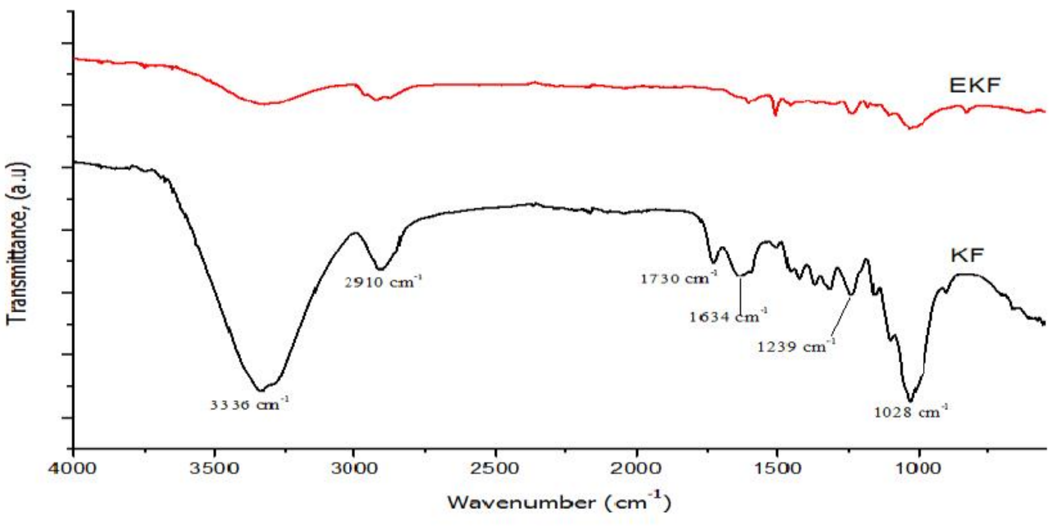

Figure 2b: The Combined spectra of raw kenaf (KF) and epoxy coated kenaf (EKF).

The associated peaks for hydrophilic properties showed a general reduction in their intensities due to the coating and treatment effects (Figure 2b). Although the difference between the two treatments is that the amount of hydroxyl groups present in the chemical treated and epoxy coated fibres were lower compared to the raw kenaf fibres as most of them have reacted with the coating epoxy resin. Same observation on reduction in hydroxyl group was reported by Tan *et al.* (2011) when empty fruit fibres were treated with maleic anhydride which led to the formation of cross-links network.

3.2 Morphological analysis of kenaf fibres by SEM

The micrographs of natural kenaf fibres (KF), NaOH treated kenaf fibre (NKF), epoxy coated-NaOH treated kenaf fibre (ENKF) and epoxy coated kenaf fibre (EKF) are shown in Figure 3. The surface view of raw kenaf fibres showed the appearance of impurities such as pectin and lignin on the samples which might be the reason for the poor bonding between the fibre and the matrix interface. This might also be responsible for the low mechanical properties of the resulting composites.

NaOH-treated kenaf fibres, NKF (Figure 3b) revealed some structural changes and a cleaned surface void of impurities as compared to the raw kenaf, KF due to chemical treatment which indicate that fibre surface treatment with NaOH removed the surface lignin, hemicelluloses and pectin substances resulting to rough topography as also mentioned by different authors (Tan *et al.*, 2011; Li *et al.*, 2007).

The epoxy coated-treated kenaf fibres (ENKF) also showed smooth surfaces which confirmed the presence of coating on the kenaf fibres (Figure 3c). Enhancement in aspect ratio and rough surface topography development is very important in improving fibre-matrix interface and their adhesion, as expected; the mechanical properties will also improve. The porous structures on the fibres have also been covered by the epoxy resin (Figure 3d), which is also expected to provide good interlocking.

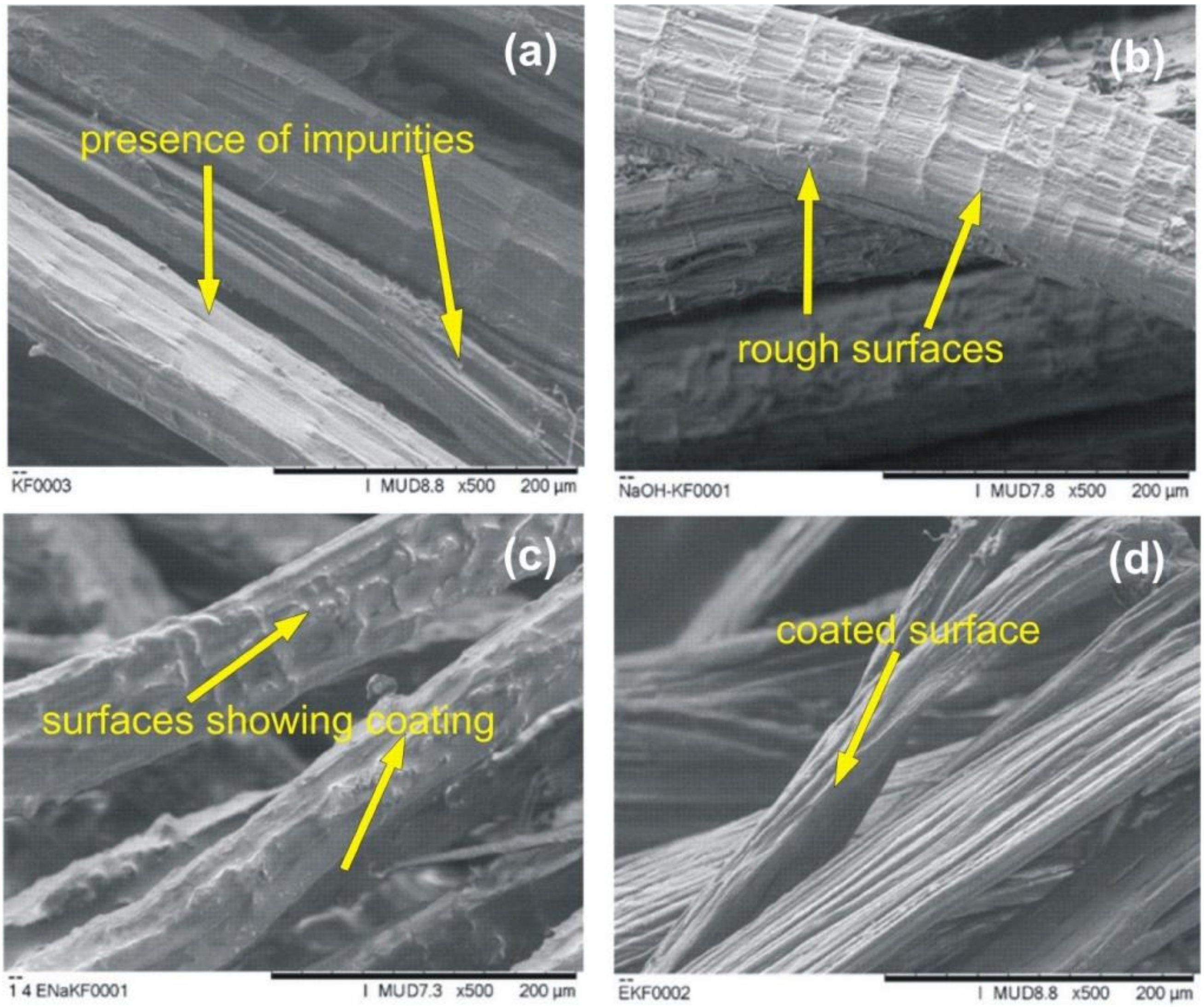

Figure 3: Morphology of (a) raw kenaf fibre (KF), (b) NaOH treated kenaf fibre (NKF), (c) epoxy coated-NaOH treated kenaf fibre (ENKF) and (d) epoxy coated kenaf fibre (EKF).

3.3 Mechanical Properties

3.3.1 Effect of chemical treatments

The tensile modulus and strength of kenaf fibre filled ABS composites due to chemical treatments are shown in Figure 4.

The tensile strength values of neat ABS, KF/ABS, ENKF/ABS and EKF/ABS composites are 42.4 MPa, 37.4 MPa, 38.6 MPa and 39.2 MPa respectively (Figure 4). The neat ABS showed strength higher than the reinforced composites which might be due to poor interface or the low fibre content used in the composite. To determine the treatment method with best performance, the fibre content of 10 wt% was kept constant, it is however, expected that the strength of the composite will increase on increasing the fibre content as seen in Figure 9.

From the chemical treatment point of view, it is observed that both modified ENKF/ABS and EKF/ABS composites all showed improved tensile strength as compared to KF/ABS composites due to improved interfacial bonding between the chemically treated kenaf (NKF), epoxy coated kenaf (EKF) and the ABS matrix. The tensile strength of EKF/ABS composites was marginally higher as compared to chemical treated ENKF/ABS composite with 1.6% improvement. The result obtained generally indicates that the tensile strength or performance from the new treatment method of surface coating the fibre with epoxy resin gave better tensile strength compared to conventional alkali treatment method of natural fibre. Hence, EKF/ABS composite gave better tensile strength than ENKF/ABS composites. Dehghani *et al.* (2013) also mentioned enhanced thermal and mechanical properties by surface coating of date leaf fibre. Tensile modulus (Figure 4) also showed the same trend as that of tensile strength. Observation is that both chemically treated ENKF/ABS and epoxy coated EKF/ABS composites all showed improved tensile modulus with same maximum modulus as compared to untreated/uncoated KF/ABS composites. It also showed that NaOH treatment is unnecessary and might not be required.

Flexural modulus and strength effect of the chemical treatments are presented in Figures 5 and 6 respectively. The flexural strength of ABS, KF/ABS, ENKF/ABS and EKF/ABS composites are 61.3 MPa, 58.2 MPa, 59.0 MPa and 61.0 MPa respectively. The high flexural strength of neat ABS showed slight reduction with the addition of fibres. The flexural strength of KF/ABS composites was found to be low indicating weak interface and poor compatibility between the hydrophobic matrix and the natural kenaf fibre and, another reason may be attributed to fibre degradation since the composites was melt mixed or processed at high temperature (240 °C) above the temperature at which natural fibres degrade. ENKF/ABS and EKF/ABS composites both yielded improved flexural strength as compared to KF/ABS.

There is a higher bonding between the coated kenaf and the ABS polymer with respect to the raw kenaf fibre composites. The reason for the improved result is the surface roughness of the fibre which must have increased causing better mechanical interlocking (Gu, 2009).

The flexural strength of ENKF/ABS composites was better than the untreated composites due to the existence of enhanced fibre/matrix interaction as a result of chemical treatment effects. The highest flexural strength is found with EKF/ABS composite and followed by chemical treated ENKF/ABS composite which improved by 3.3% and 4.6% compared to ENKF/ABS and KF/ABS composites respectively. An indication that the new treatment method of surface coating with epoxy resin yields better flexural properties than the conventional sodium hydroxide treatment method.

The flexural moduli (Figure 6) of all reinforced composites were more than the neat ABS. The flexural modulus of ABS increased upon the incorporation of fibres which is in direct contrast with the flexural and tensile strength results earlier discussed in Figures 4 and 5 where ABS showed a slight reduction in strength with the incorporation of fibres and later improved significantly with chemical treatment and surface coating. It is further observed that EKF/ABS composites showed maximum flexural modulus (2392.59 MPa) indicating that epoxy coating of fibres and its composites yield better flexural results than the use of alkali treatment.

The impact strength and absorbed energy values of neat ABS, KF/ABS, ENKF/ABS and EKF/ABS composites are shown in Figures 7 and 8. Neat ABS showed increased impact strength when fibres were incorporated, which further improved with surface coating and treatment. To compare treatments, the impact strength of all reinforced composites were better than the unreinforced ABS.

Chemical treated ENKF/ABS and epoxy coated EKF/ABS composites exhibited superior impact strength as compared to KF/ABS composite showing enhanced efficiency of stress transfer from the matrix to the KF (Owen *et al.*, 2018).

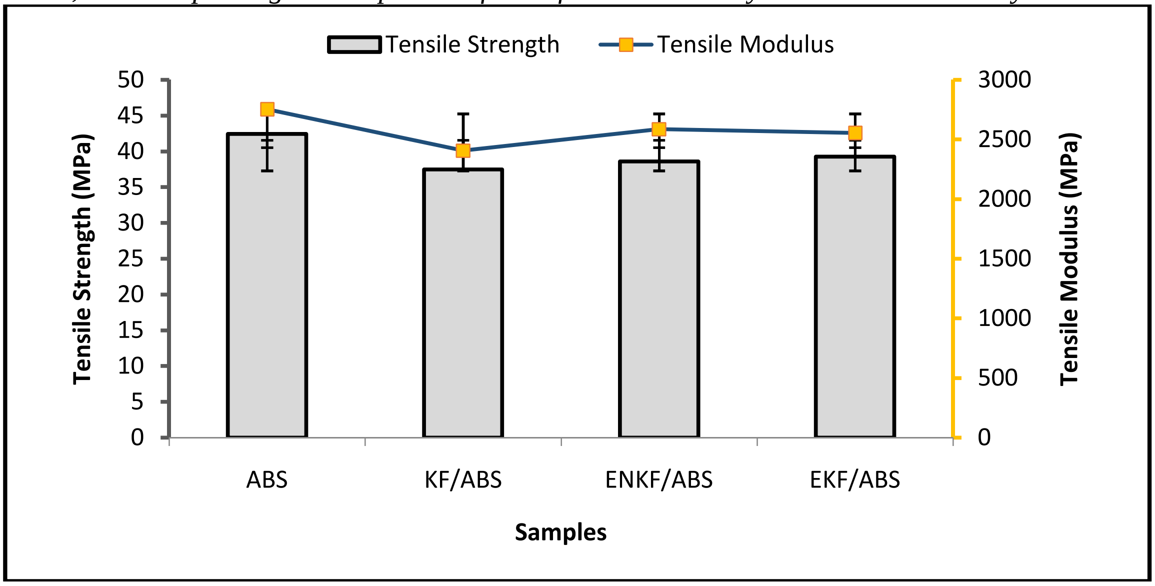

Figure 4: Several chemical treatments and their effect on the tensile strength and moduli of kenaf fibre filled ABS composites at 10 wt% constant fibre loading.

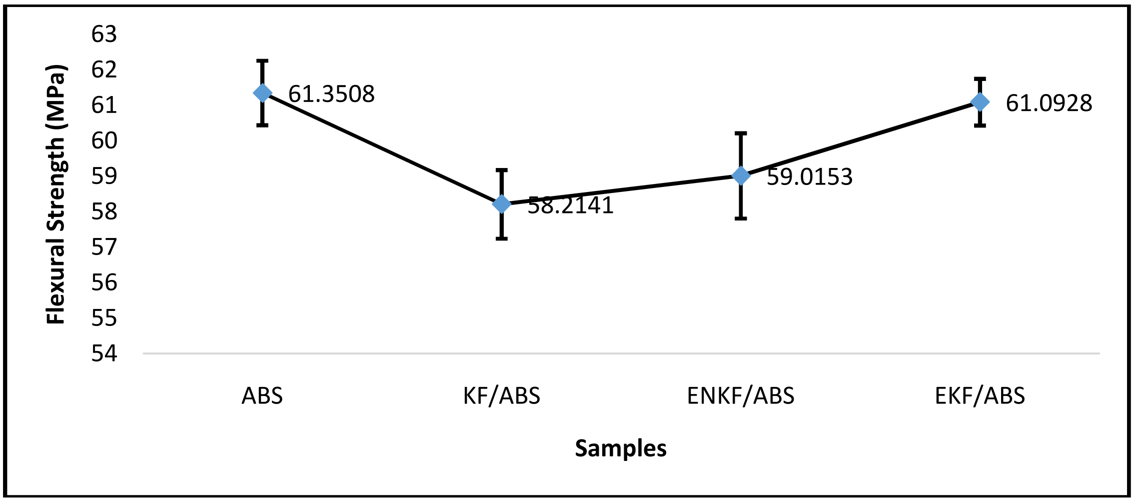

Figure 5: Chemical treatments effects on the flexural strength of kenaf fibre filled ABS composites at 10 wt% constant fibre loading.

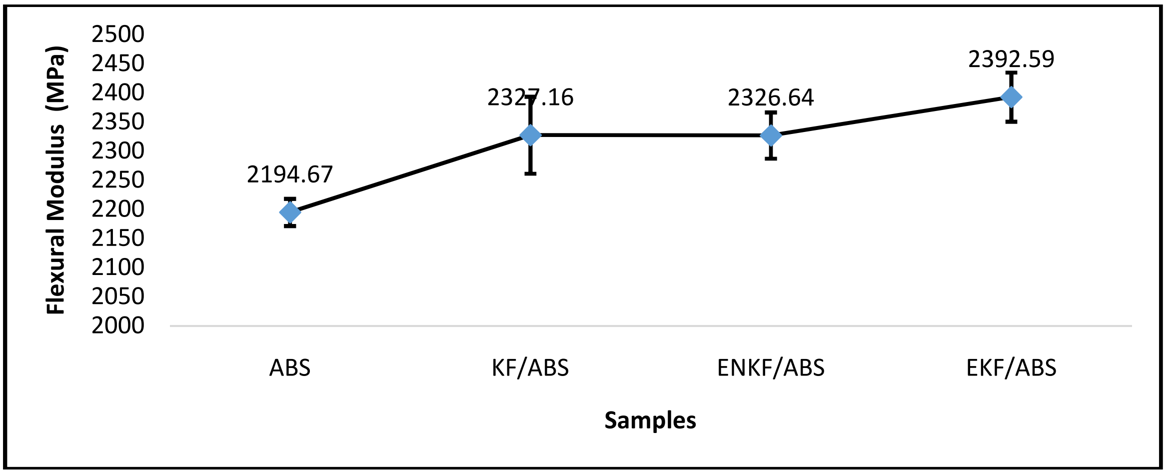

Figure 6: Chemical treatment effects on the flexural modulus of kenaf fibre filled ABS composites at 10 wt % constant fibre loading.

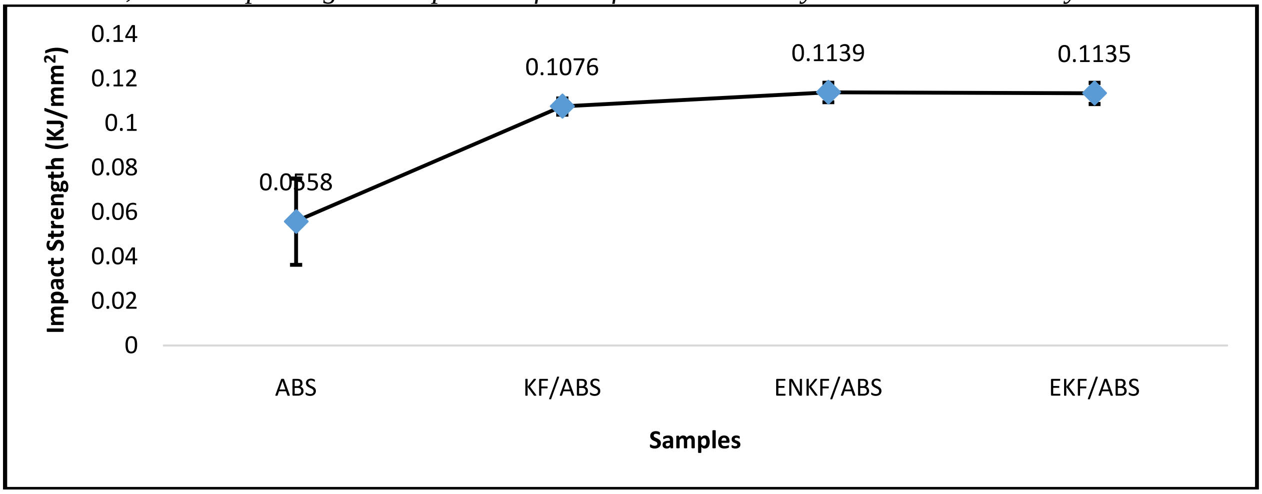

Figure 7: The chemical treatment effects on the impact strength of kenaf fibre filled ABS composites at 10 wt% constant fibre loading.

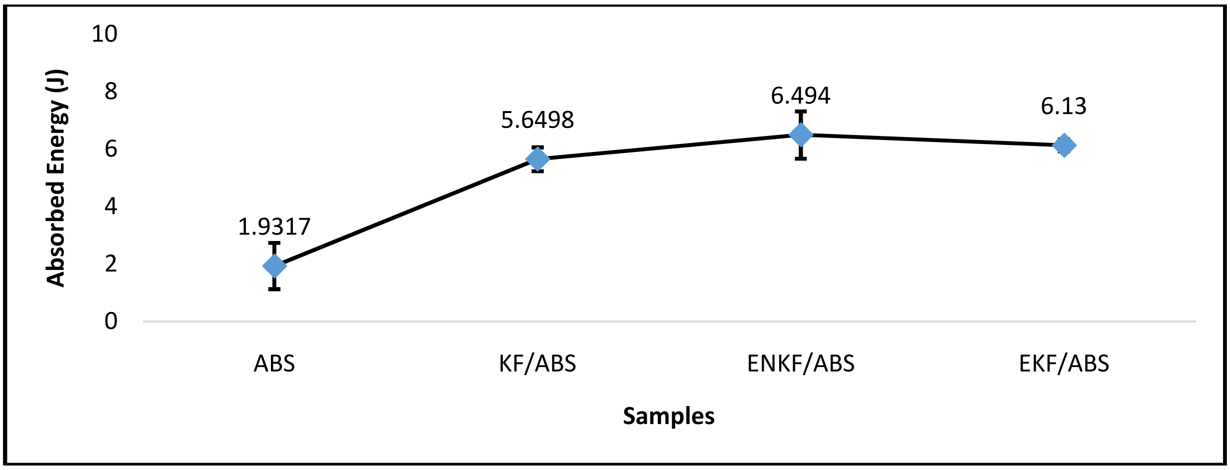

Figure 8: Chemical treatment effects on the impact absorbed energy of kenaf fibre filled ABS composites at 10 wt% constant fibre loading.

This could be attributed to the enhanced interface due to NaOH treatment and epoxy coating effects, and existence of strong intermolecular bonding between the treated and coated fibre and ABS (Saliu *et al.*, 2015b). Nuthong *et al.* (2013) recorded similar behaviour in their flexible epoxy treated natural fibres PLA composites.

In Figure 8, ABS polymer only absorbed lesser amount of energy as compared to the constituent composites. More energy was dissipated with incorporation of fibre and the resultant composites absorbed more energy than the unreinforced ABS. The KF/ABS composites has less ability to absorb impact energy as compared to surface treated and coated composites samples due to weak bonding interface between the natural kenaf and ABS polymer matrix. Maximum energy of 6.49 J was found with ENKF/ABS composites and followed by EKF/ABS with absorbed energy of 6.13 J.

3.3.2 Effect of fibre loadings

Since fibre content is of significant importance to properties of natural fibre reinforced composites, high amount of fibre content is required to achieve the high performance of the composites (Sapuan *et al.*, 2013). In this work, only ENKF/ABS composite was used to determine the influence of fibre content on the performance of the composites. The result obtained on the effects of fibre loading on the tensile strength and moduli of kenaf fibre filled ABS composites are presented in Figure 9 and 10 respectively.

Tensile strength is found to improve with high fibre loading (Figure 9). 15 wt% fibre loading gave maximum strength with a value of 41.7 MPa. The result is an indication that in addition to improved properties with surface coating and treatment, maximum performance could also be achieved with high amount of fibre content. Nishino *et al.* (2003) also recorded increased tensile properties on kenaf fibre content increase.

In a previous study on kenaf reinforced recycled PET composite (Owen *et al.*, 2019), increase in tensile strength was recorded due to increase in fibre loading. Surface coated fibres in composites gave a positive increase for tensile strength with increase in fibre content from 5-15 wt% compared to uncoated composites. The modulus (Figure 10) also increased as the fibre content increased with highest modulus value of 2652.8 MPa found at 15 wt% fibre loading.

The flexural strength (Figures 11) of the composites decreased as the fibre loading increased up to 15 wt%, maximum strength of 60.7MPa was found at 5 wt% fibre loading.

In Figure 12, the neat ABS has a flexural modulus of 2194.6 MPa which also increased with addition of kenaf fibre. The highest modulus was at 15 wt % loading with a value of 2469.1 MPa. The results obtained have indicated that the amount of fibre content is a factor for consideration in the performance of kenaf fibre filled ABS composites. The composites showed a significant reduction in bending strength whose modulus increased with increase in fibre loading.

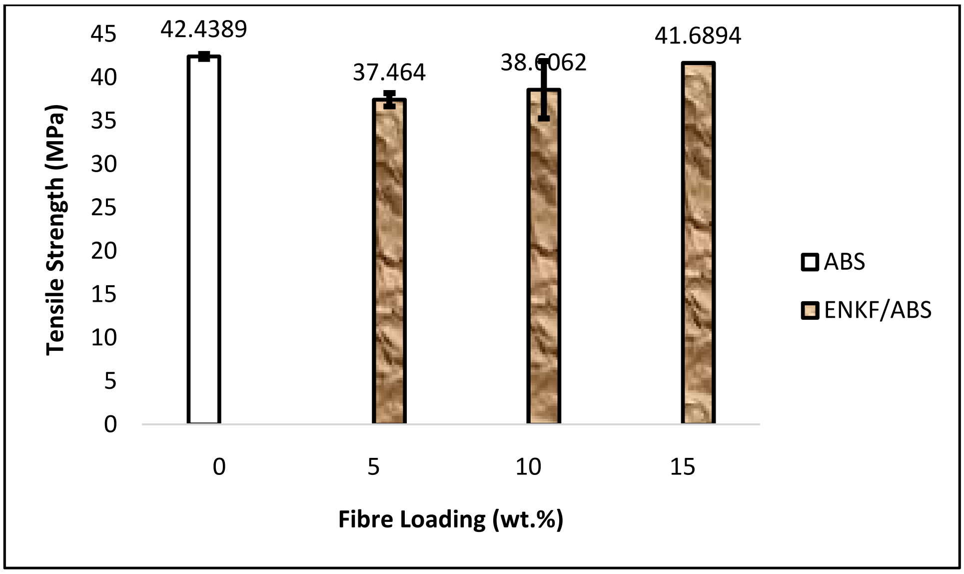

Figure 9: Effect of fibre loading on the tensile strength of kenaf fibre filled ABS composites

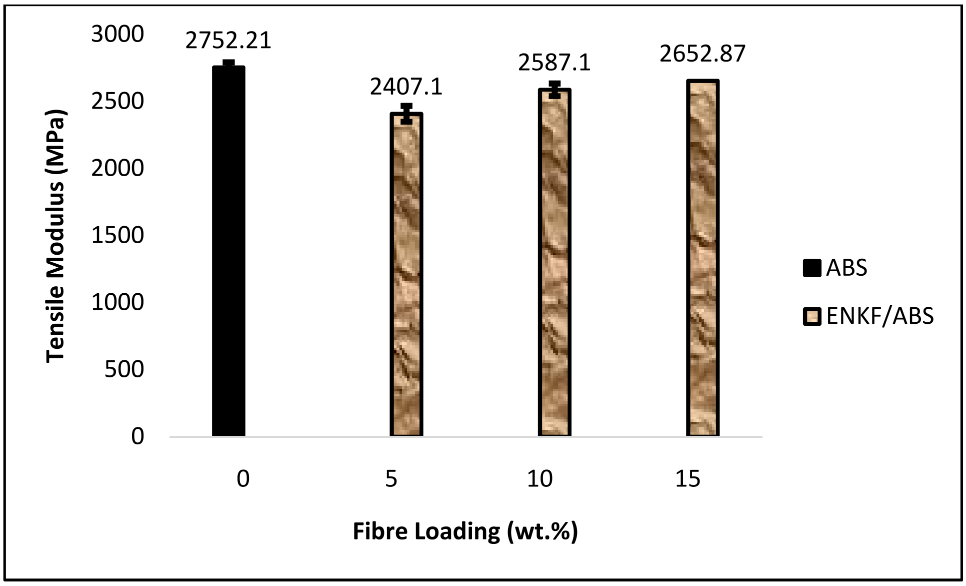

Figure 10: Tensile modulus of kenaf fibre filled ABS composites at different loadings

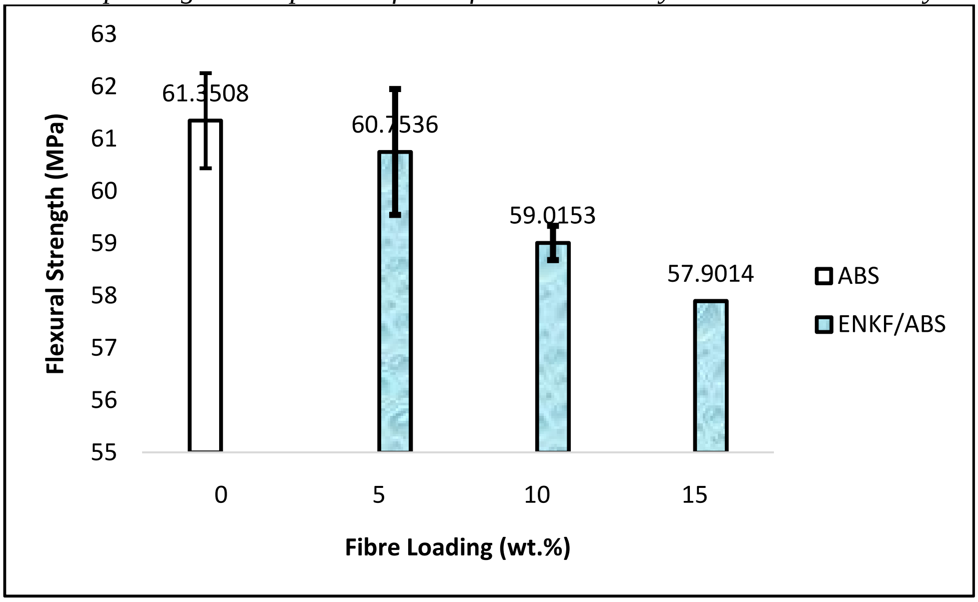

Figure 11: Flexural strength of kenaf fibre filled ABS composites at different fibre loadings

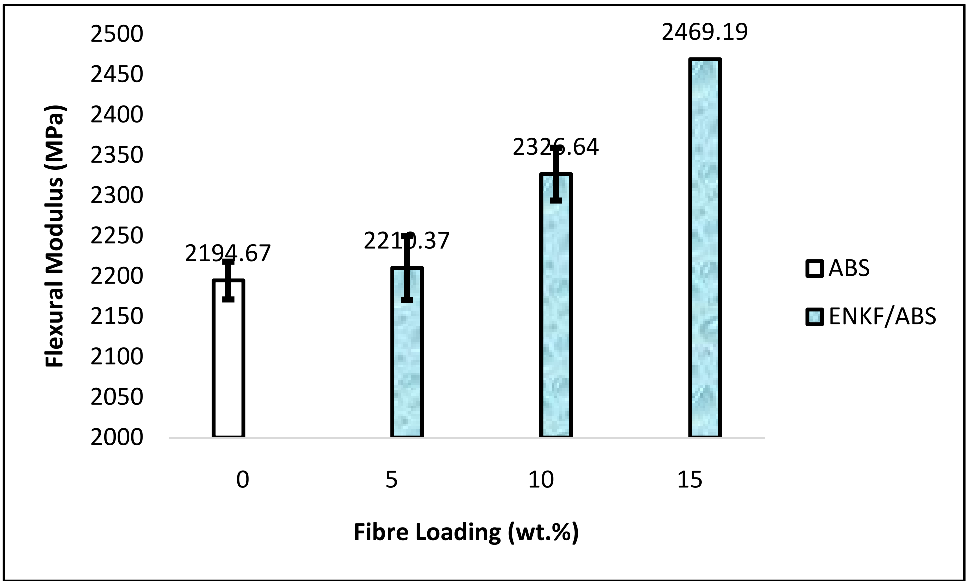

Figure 12: Flexural modulus of kenaf fibre filled ABS composites at different fibre loadings

Figures 13 and 14 show the results of the impact strength and absorbed energy for kenaf fibre filled ABS composites. The impact strength of unreinforced ABS increased on incorporation of fillers. Strength of composites decreased with increased in fibre loading. Maximum strength was at 5 wt% which dropped at 10-15 wt% loadings.

The work of Nuthong *et al.* (2013) on impact strength of epoxy treated fruit fibre/PLA showed decreased strength because the fibres could not improve the brittleness of the PLA matrix. The current study have shown that ENKF/ABS composites exhibited improved impact strength as compared to neat ABS matrix due to the presence of strong intermolecular force between the epoxy and the fibre. In a similar manner, 5 wt% filler content absorbed more energy (7.82 J) than other constituent composites (Figure 14).

The found decrease in energy with increased loading might be due to agglomerations at high fibre loading. Thus, ENKF/ABS composites showed improved impact properties due to the surface treatment and coating effect on the fibre.

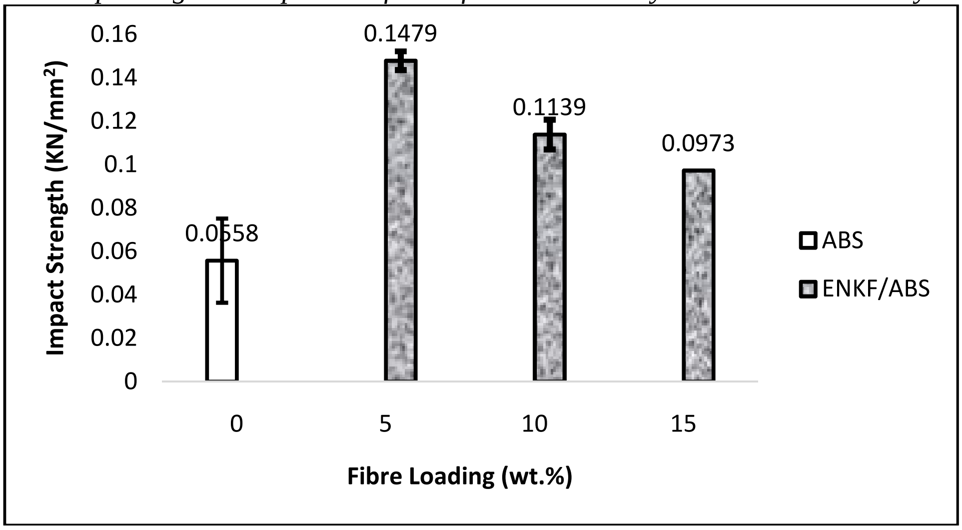

Figure 13: Impact strength of kenaf fibre filled ABS composites at different fibre loadings

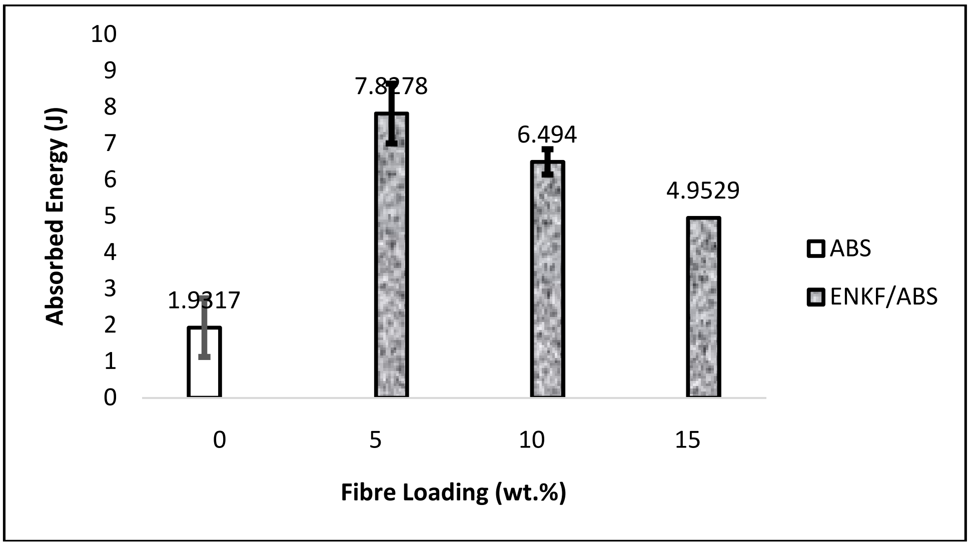

Figure 14: Impact absorbed energy of kenaf fibre filled ABS composites at different fibre loadings

3.4 Morphological properties

3.4.1 Effect of chemical treatment

The results of the morphological analyses of natural kenaf (KF/ABS), treated kenaf (ENKF/ABS) and coated fibre (EKF/ABS) composites are presented in Figures 15(a-b), (c-d), and (e-f) respectively. Several FESEM images were taken at various directions to characterize the resultant composites.

The FESEM micrograph of fracture surface morphology of natural kenaf KF/ABS composites (without fibre treatment) in Figure 15(a-b) revealed cracked portions and gaps between the fibre wall and ABS matrix which signifies incompatibility. Azwa and Yousif, (2013) attributed the cracks to the debonding at the fibre-matrix interface which progress to the composite surface. This causes weak bonding between the fibre and matrix and poor mechanical properties of the composites as observed in Figures 4 and 5. Evidence of fibre pullout and holes are also visible in the composites system.

There is an improved bonding between the treated fibre and matrix ABS molecular chain for the NaOH treated kenaf ENKF/ABS composites (Figure 15 (c, b)). An indication of the chemical treatment effect which may have deactivated the hydroxyl groups in the treated kenaf fibre resulting in effective chemical interlock with the ABS matrix. However, ENKF/ABS composites revealed a strong fibre /matrix interfacial bonding which might be the primary cause for the outstanding mechanical properties over the untreated composites. Same can be said for coated kenaf EKF/ABS composites (e, f). This has led to the superior mechanical strength recorded in Figures 4 and 5 compared to the NaOH treated kenaf ENKF/ABS and the natural fibre KF/ABS composites.

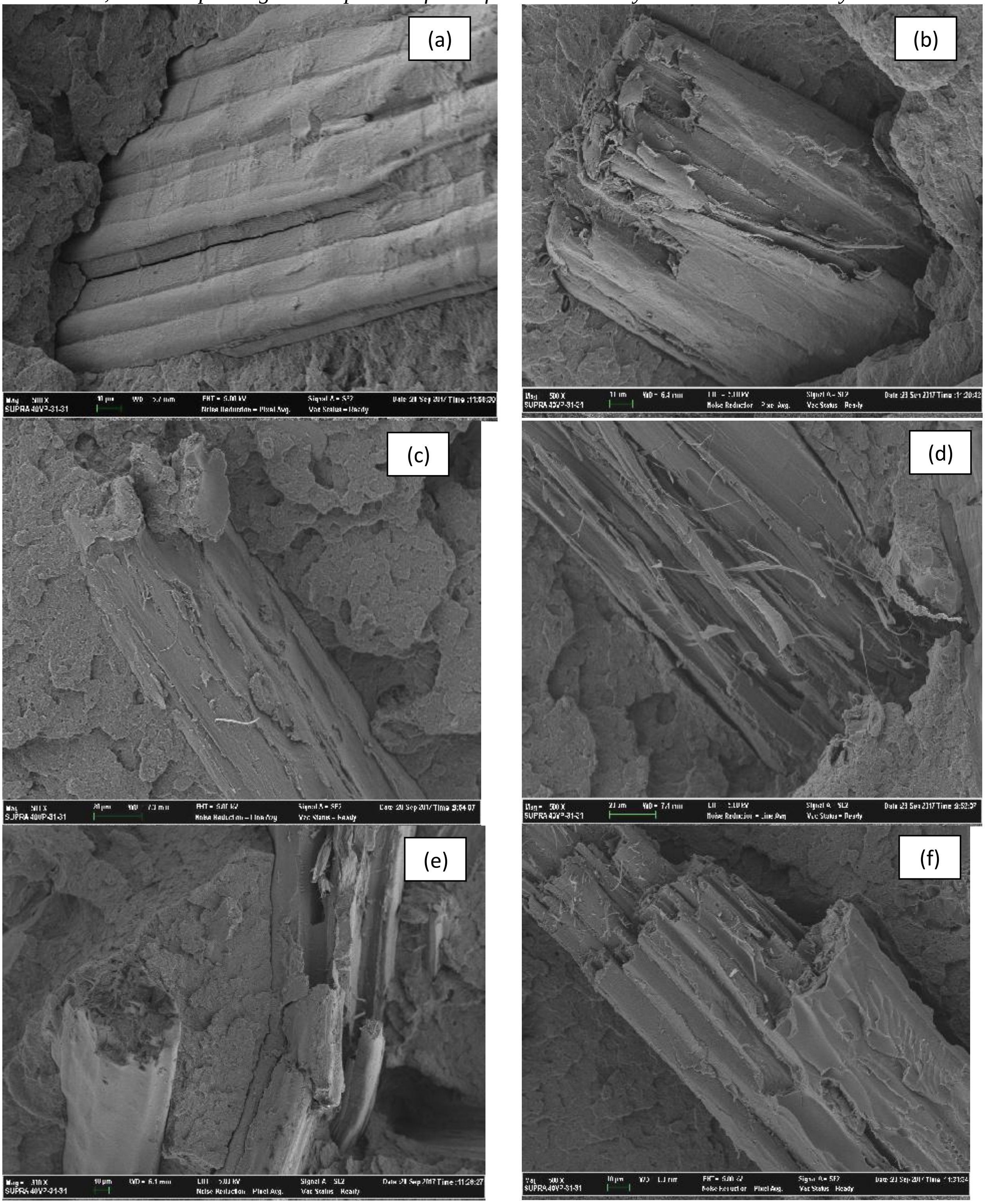

Figure 15: FESEM micrograph of raw kenaf, **KF/ABS** (a, b), epoxy-coated NaOH treated kenaf, **ENKF/ABS** (c, d) and epoxy-coated kenaf, **EKF/ABS** (e, f) composites.

3.4.2 Effect of fibre loading

The fractured micrographs of the epoxy coated ENKF/ABS composites at different fibre loadings (5, 10 and 15 wt%) are shown in Figure 16. The composites micrographs all showed clear evidences of structural integrities being retained even at higher fibre loading of up to 15 wt% because of the coating effect. Fibres pull out; damages and delamination were not prevalent as seen in the uncoated KF/ABS composites (Figure 15).

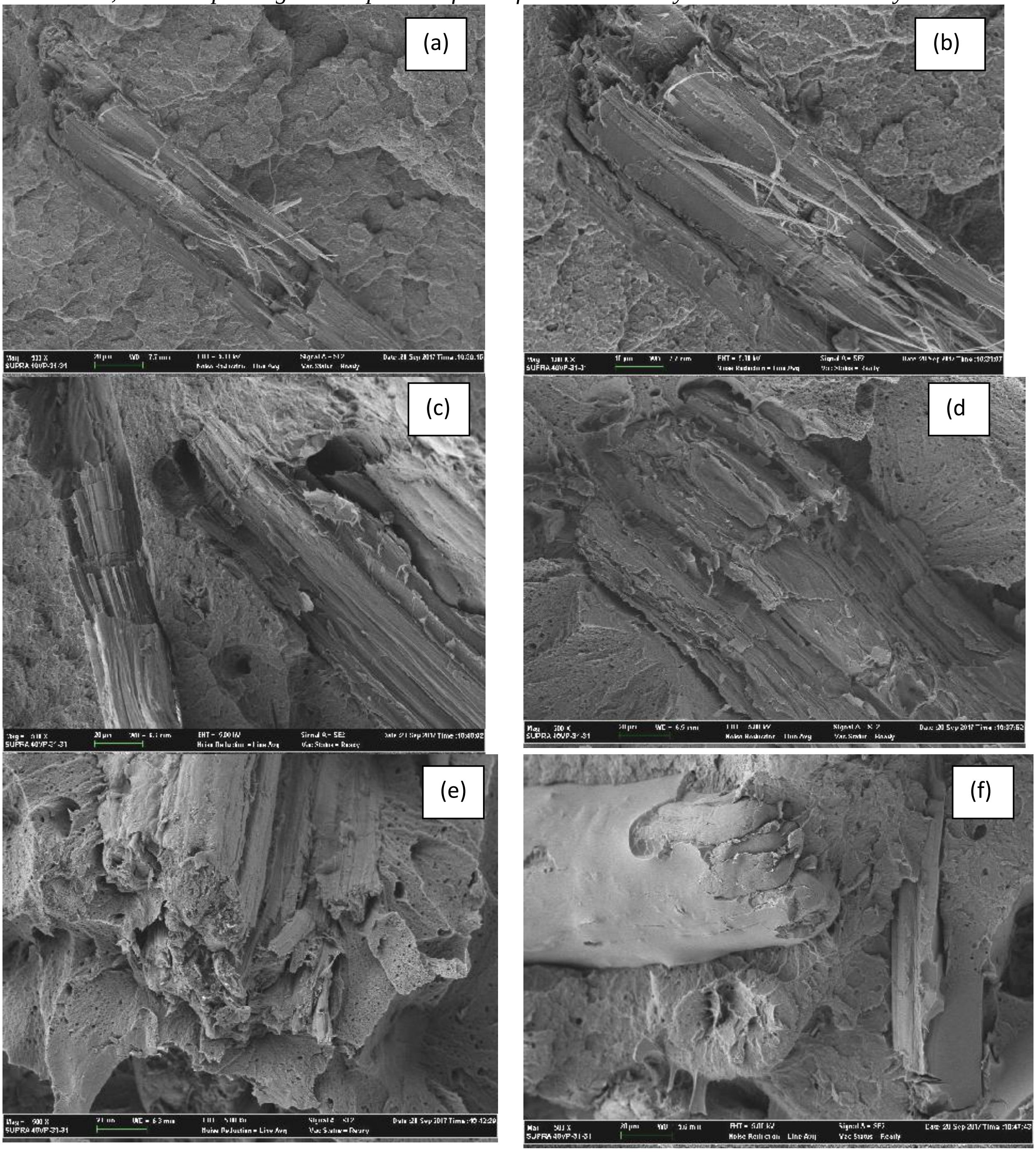

Figure 16: FESEM micrographs of epoxy-coated NaOH treated kenaf (ENKF/ABS) composites at 5 wt% (a, b), 10 wt% (c, d) and 15 wt% (e, f)) fibre loadings.

CONCLUSION

Composites of kenaf bast fibre reinforced high temperature thermoplastic (ABS) using the new treatment technique in comparison with conventional alkali treatment method was studied with the view to evaluating their effectiveness. The following conclusions are drawn:

- Epoxy coating of kenaf fibres as a treatment method is more effective than the conventional alkali treatment in improving mechanical properties as epoxy coated (EKF/ABS) composites gave the best results with substantial improvement in mechanical properties (flexural strength of 61.093 MPa and impact strength of 0.1135 kJ/mm^2) compared to epoxy-coated NaOH treated kenaf (ENKF/ABS) and raw kenaf fibre (KF/ABS) composites (flexural strength of 58.21 MPa and impact strength of 0.1076 kJ/mm^2).
- Treatment of kenaf fibres with NaOH for improving the interfacial adhesion in composites fabrication might be unnecessary if coating is to be done thus, reducing production cost. FESEM studies validated the improved EKF/ABS and ENKF/ABS strong fibre/matrix interface bonds between the coated, treated fibres and ABS matrix.

- Kenaf fibre composite properties can thus be improved further by coating and this will find increased applications in industrial productions if properly put to use.

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