

Treatment's Effect on Mechanical Properties of Kenaf Bast/Natural Rubber Latex Foam

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Non-treated and silane-treated kenaf bast/natural rubber latex foam (NRLF) were prepared using the Dunlop method at different filler loading (0, 3, 5, and 7 pphr). The properties were investigated in terms of mechanical properties, tensile, compression, hardness, and swelling behavior. Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) were used to characterize kenaf bast/NRLF. With the modulus at 100% elongation (M100), the compression strength and hardness showed increments in value with increments of kenaf loading. However, different results showed in tensile strength, elongation at break, swelling percentage, and recovery percentage, which decreased at higher filler loading. Silane-treated kenaf bast/NRLF showed higher value in all properties except for elongation at break, swelling, and recovery percentage. The improvement of properties was supported by SEM surface morphological studies that showed better adhesion between the rubber matrix and kenaf filler.

Keywords: Silane treatment; Kenaf bast; Natural rubber latex; Foam

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INTRODUCTION

The *Hevea brasiliensis* tree is the source of natural rubber latex (NRL), which is an important material for manufacturing (Ramasamy *et al.* 2013). Besides being tremendously economic, natural rubber latex also is a natural product with strategic importance (Roslim *et al.* 2012). Natural rubber latex is common in the production of extruded threads, dipped goods, adhesives, carpet-backing, and molded foams (Karim *et al.* 2018). Concerning the natural rubber (NR), the utilization of natural rubber latex in liquid form is the most well-known and traditional way to produce foams. Chemical stabilization, which can be accomplished through the addition of ammonia, is necessary due to the colloidal nature of latex (Ariff *et al.* 2008). The NR latex foam (NRLF) is one of the applications of NR latex. The synthesis process of NR latex foam has been carried out according to the common Dunlop manufacturing method. Since ancient times, the Dunlop manufacturing method has been the most reliable and economical method of making NRLF (Rathnayake *et al.* 2014).

Recently there has been widespread research interest in the development of polymer composites using green natural bio-fillers. This is because of the advantages possessed by a natural fiber composite, such as being lightweight, low cost, and having a high modulus and specific strength, along with being renewable in nature, a comparative advantage over synthetic fiber that is disposable and recyclable (Abdul Wahab and Hussein Shah 2018). Saheb and Jog (1999) reported that one of the major advantages of using natural fibers is higher specific properties when desired properties are needed. Saheb and Jog (1999) discussed that specific modulus of natural fibers are better than glass fibers, which lead to

comparable mechanical properties to those of glass fiber.

Flax, kenaf, hemp, and jute are bast cellulosic fibers that have an appealing potential as reinforcements in composites (Huo *et al.* 2013). One of the natural fibers, kenaf, has been used as a reinforcement in polymer matrix composites (Hao *et al.* 2018). Kenaf (*Hibiscus cannabinus* L., family Malvaceae) has been intensively planted to replace tobacco plantations in Malaysia (Kuthi *et al.* 2018). As one of the natural fibers, kenaf is mostly used because of its capability of fast growth, which delivers a large volume of raw material in a short period of time (Kamal 2014).

Lacking interfacial adhesion between the natural fiber fillers and polymer matrix is one of the potential drawbacks in producing good biocomposites (Lee *et al.* 2009). The increment of hydrophilicity of fiber due to the large presence of hydroxyl groups in cellulose leads to incompatibility with hydrophobic polymer matrices that affect the strength of interfacial adhesion between fiber and matrix, resulting in low mechanical properties and performance of the composites (Huo *et al.* 2013). To overcome this problem, several methods of chemical modification by treatment have been identified and succeed at enhancing the fiber-matrix interface, such as alkali treatment, acetylation, silane treatment, and nucleation (Tran *et al.* 2014). In previous work, Ismail *et al.* (2001) reported that the incorporation of a silane coupling agent, 3-aminopropyl triethoxysilane (3-APE), improved tensile and water absorption properties on white rice husk ash-polypropylene/natural rubber composites, indicating that the use of the coupling agent enhances the filler-matrix interaction. Karim *et al.* (2018) studied the improvement of tensile properties and thermal stability of kenaf-filled NRLF by alkaline treatment. The results showed that tensile strength increased approximately 18% while elongation at break increased approximately 21% for treated samples. For thermal stability, the result showed an increment in value of approximately 10% for treated samples.

To the best of our knowledge, no study has reported on the use of coupling agent in NRLF. Thus, in this study, silane treatment was chosen to improve the interfacial adhesion between kenaf bast filler with NRL matrix of foam. Bis(triethoxysilylpropyl)-tetrasulfide (Si-69) as coupling agent was used in this work. The goal was to study the effect of silane treatment on mechanical and morphology properties of kenaf bast-filled foams. Improvement in tensile, compression, hardness and swelling properties which supported with characterization of FTIR and surface morphology proved the effectiveness of silane as coupling agent in kenaf bast/NRLF.

EXPERIMENTAL

Materials and Formulation

Table 1 exhibits the formulation used in this study. Bast kenaf fibres were dried, ground, and sieved into an average particle size of 70 μm . Zarm Scientific & Supplies Sdn. Bhd. Bukit Mertajam, Malaysia was the supplier for most of the materials, including high ammonia (HATZ)-type NR latex, sulphur, antioxidant, potassium oleate, zinc diethyldithiocarbamate (ZDEC), zinc 2-mercaptobenzthiozate (ZMBT), zinc oxide, diphenylguanidine (DPG), and sodium silicofluoride (SSF). Kenaf bast was supplied by the National Kenaf and Tobacco Board, Kota Bharu, Malaysia. Bis(triethoxysilylpropyl)-tetrasulfide (Si-69) as coupling agent was supplied by Bayer (M) Ltd., Leverkusen, Germany.

Table 1. Kenaf Bast/Natural Rubber Latex Foam Formulation

Ingredients	Formulation	
	Total Solid Content (TSC%)*	Parts per Hundred Rubber (pphr)
HA Latex	60	100
Sulphur	50	2.2
Antioxidant	50	1
Potassium Oleate	20	4.5
ZDEC ¹	50	0.9
ZMBT ²	50	0.9
Zinc Oxide	50	3
DPG ³	40	0.3
SSF ⁴	25	1.2
Kenaf Bast	-	0/1/3/5/7

*TSC%- percentage by weight of the whole, which is non-volatile at definite temperature; ¹ zinc diethyldithiocarbamate; ² zinc 2-mercaptobenzthiozate; ³ diphenylguanidine; ⁴ sodium silicofluoride

Sample preparation

The required amount of high ammonia latex concentrate (HATZ) was filtered and measured as shown in Table 1. Then, using a mechanical stirrer, the HATZ was stirred for approximately 10 min at 100 rpm. After 10 min, sulphur (vulcanizing agent), ZMBT, and ZDEC (accelerator) were slowly added into the mixture for approximately 15 min, followed by the kenaf bast addition with continuous stirring for approximately 1 h. Potassium oleate (foaming agent) was slowly added into the NRLF compound and then matured for 6 h at room temperature with a continuous stirring speed of 100 rpm. After 6 h of continuous stirring, the NRLF compound underwent the foaming process. Using a stand mixer (Kenwood, kMix, Havant, England) the NRLF compound was beaten intensively for 5 min until the volume was increased up to three times the initial volume. The foaming process was performed at speed level of 6 until the desired volume was achieved, then the speed was lowered to obtain a fine and even foam. Next, ZnO and DPG as primary gelling agents were added for 1 min followed by the addition of a secondary gelling agent, SSF, for approximately 15 s. The un-gelled mixture was formed and quickly poured into an aluminium mold to obtain the desired shape and gelling process was completed by leaving the mixture at an ambient temperature for 3 min. The curing process of gelled foam was then performed in an oven at 105 °C for 2 h. After the curing process was achieved, the foam was stripped from the mold and washed thoroughly with distilled water to remove excess non-reacted material. The drying process was completed in the oven at 80 °C for 8 h. These steps were used for both untreated and treated kenaf bast/NRLF preparation and repeated without kenaf bast for preparing the control sample.

Methods

Fiber treatment

A 20% solution was made by dilution of 1% of Si-69 by weight of the filler in ethanol. Next, filler was charged into a stand mixer and the solution was added slowly for uniform distribution of Si-69. The filler was continuously mixed for approximately 30 min, followed by a drying process at 100 °C in an oven for approximately 5 h to allow complete the evaporation of the ethanol.

Measurement of tensile properties

Tensile properties, such as tensile strength, tensile modulus, and elongation at break, were obtained by tensile tests using an Instron universal testing machine model 3366 (Instron, Norwood, MA, USA). Tests were conducted according to ASTM D412-06a (2006). Five dumbbell specimens of each kenaf loading for both untreated and treated kenaf bast/natural rubber latex foam were cut from molded sheets using a Wallace die cutter (GS Engineering Sdn Bhd, Klang, Selangor) and tests were performed at 25 °C. A crosshead speed of 250 cm min⁻¹ was used.

Compression test measurement

Compression tests for the kenaf bast/NRLF were conducted using an Instron 3366 machine in accordance with ASTM D3574 (2003). The dimensions for the samples were 50 mm × 50 mm × 25 mm. Tests were performed at 50 mm/min speed and 25 °C. Five specimens for each loading were compressed until it reached 50% of their original thickness. The stress *versus* kenaf loading at 50% compression was obtained.

Compression set measurement

Compression set measurements were evaluated according to ASTM D1055-97 (1997). Three specimens were used in this testing with the dimensions 50 mm × 50 mm × 25 mm. The samples were compressed to 50% of their original thicknesses using two plates of compression devices. Compressed specimens were placed in the oven at 70 °C for 22 h along with the apparatus. After 22 h, specimens were quickly removed from the apparatus. The thickness measurement was taken after a 30-min recovery. The recovery percentage was calculated according to Eq. 1:

$$\text{Recovery (\%)} = \frac{\text{Final thickness of specimen (mm)}}{\text{Original thickness of specimen (mm)}} \times 100 \quad (1)$$

Hardness

The hardness test of kenaf bast/NRLF (Table 2) was conducted using the Foam and Sponge Rubber Durometer 302SL (PTC Instruments, Los Angeles, CA, USA) with sample dimensions of 55 mm × 30 mm × 25 mm (length × width × thickness).

Table 2. Foam and Sponge Rubber Durometer 302SL Value Ranges (Bashir *et al.* 2017)

Class	Value Range
X-Soft	19 to 27
R32-Soft	27 to 42
R33-Medium	42 to 66
R34-Firm	66 to 90
R35-Xfirm	90 to 100

Swelling

Samples of kenaf bast/NRLF were cut into dimensions of 30 mm × 5 mm × 2 mm and weighed. Then, samples were immersed in toluene. Samples were placed into a closed bottle and allowed to swell for 72 h. After 72 h, samples were removed, and surfaces of the swollen tested samples were wiped. Tested samples were weighed before the swelling percentage was calculated according to Eq. 2:

$$\text{Swelling (\%)} = \frac{\text{Swollen weight} - \text{Initial weight (g)}}{\text{Initial weight (g)}} \times 100 \quad (2)$$

Fourier transform infrared (FTIR) spectroscopy

Fourier transform infrared spectroscopy (Perkin Elmer System 2000; PerkinElmer Inc., Waltham, MA, USA) was used to detect chemical changes in tested samples. Wavenumbers used to record FTIR spectra were within the range of 550 to 4000 cm^{-1} with an average of 24 scans.

Scanning electron microscopy (SEM)

Scanning electron microscopy (TM100; Hitachi Ltd., Chiyoda-ku, Tokyo) analysis was performed to study the surface morphology of both untreated and treated kenaf bast/natural rubber latex foam. The foam surfaces were sputter-coated with a thin layer of gold using a Polaron SC 515 sputter coater (Bio-rad, Hercules, CA, USA) to avoid electrostatic charging and poor image resolution during testing. The comparison of pore morphologies and rubber-filler adhesion for both untreated and treated kenaf bast/NRLF was observed.

RESULTS AND DISCUSSION

Tensile Properties

Figure 1 displays tensile strength of natural rubber latex foam (NRLF). As shown, tensile strength dropped as soon as filler was added at 1 pphr. A similar observation was reported by Borkar *et al.* (2007), that the tensile strength of the control sample without filler showed higher tensile value compared to the filled sample. The trend consistently dropped as more filler was added at higher filler loading. This was because the presence of filler required more surface to be wetted by the matrix. An empty gap between spaces full of fillers could occur. This leads to ineffective contact between filler and matrix. The reduction in the effectiveness of filler-matrix interaction caused insufficiency in creating bonding between filler and matrix. As a result, ineffective stress transfer in the system reduced the tensile strength (Fairuz *et al.* 2016). However, higher value of tensile strength for treated sample at the same filler loading compared to control sample was due to improvement of filler-matrix adhesion. This advantage indicate the effectiveness of silane coupling agent to improved compatibility between filler and matrix.

Moreover, as filler loading increases, the fillers tend to agglomerate to each other. This can be explained by considering the kenaf bast structure. Kenaf bast has a fibrous shape that is easy to agglomerate at high filler loading. According to Akil *et al.* (2011), the main obstacle in using kenaf fiber as filler reinforcement in composites is the difficulties in manually separating and visually dispersing it evenly in the course of manufacturing. The agglomeration creates a high stress concentration area that prevents effective stress transfer in the system. Thus, tensile strength reduced with increment of filler loading.

As more filler was added, the amount of porosity in foam increased (Borkar *et al.* 2007). As discussed earlier, the agglomeration happened at higher filler content and sizes of pores will increase, which will also lead to the reduction of wettability between filler within the matrix and reduced tensile. Tensile strength of both untreated and treated samples show lowest tensile strength value at highest filler loading (7 pphr) due to filler agglomeration. This result will be support by SEM image later.

Generally, the higher the value of tensile strength, the better the performance of the material (Fairuz *et al.* 2016). Based on Fig. 1, tensile strength of treated kenaf bast/NRLF showed higher value than the untreated sample. This phenomenon occurs due to the presence of silane, which enhanced wettability of kenaf by the matrix. Without a coupling agent, the only adhesion mechanism is interdiffusion (Rao *et al.* 2018). The presence of a silane-coupling agent enhanced the formation of hydrogen and covalent bonding between the hydroxyl groups of filler and polysiloxanes through hydrogenation of silanes. This provide better adhesion between the fiber and the matrix. Increment of tensile strength after silane treatment due to better adhesion can be explained by the improvement of stress transfer through fiber. Abdul Wahab and Husseinshah (2018) reported a similar observation in their study on the effect of modified filler surface with a silane coupling agent on mechanical properties of unsaturated polyester composite. Composite added with chemically modified filler showed higher tensile strength compared to composite obtained without the chemical modification.

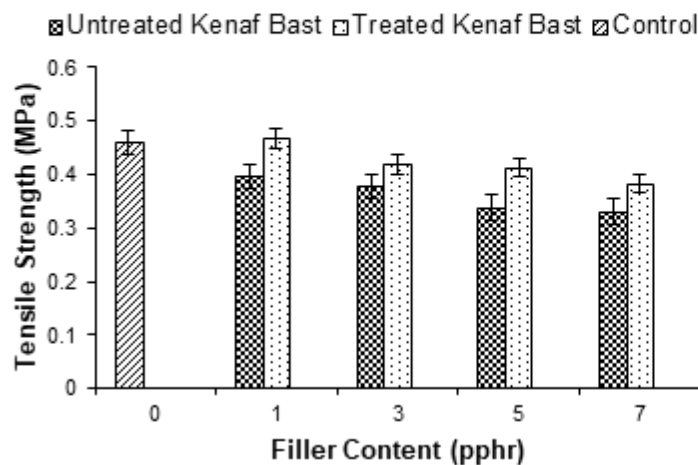


Fig. 1. Tensile strength of kenaf bast-filled foam *versus* filler content and comparison between untreated and treated kenaf bast/NRLF

Figure 2 depicts that elongation at break gradually decreased as the filler content increased. The elongation at break value started to drop after filler addition at 1 pphr. Theoretically, the behavior of composite changed from ductile to brittle at high filler loading (Fu *et al.* 2008). The presence of filler in flexible rubber chains caused a restriction to the matrix mobility. Thus, the more filler added into the matrix, it tended to be difficult to have greater elongation.

The result of elongation at break of both treated and untreated kenaf bast/NRLF at the same filler content are compared in Fig. 2. Elongation at break was reduced further as treated kenaf was added into the foam. Better bonding between filler and matrix reduced the elasticity, resulting in more stiff and rigid composites. Silane as a bifunctional coupling agent acts as a bridge to allow polar matrix and nonpolar filler to be coupled together (Pickering *et al.* 2015). On elongation, the strong bonding prevents filler from sliding easily within the matrix. This leads to lower resistance to break. Pang *et al.* (2018) reported lower elongation at break of the treated kenaf filled composite than that of the untreated kenaf filled composite as it had reduced ductility in the composite due to better interfacial adhesion.

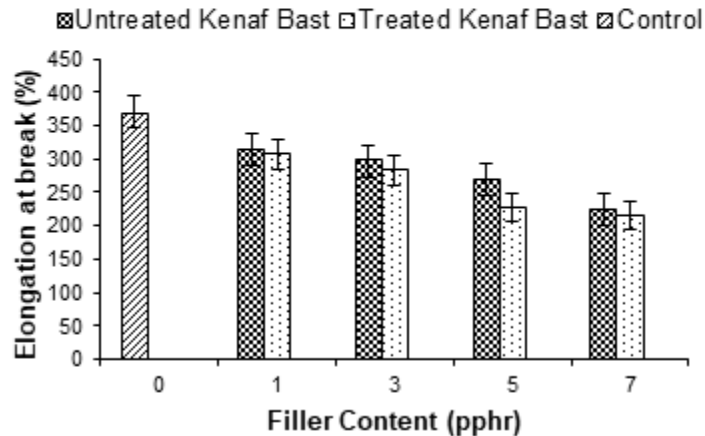


Fig. 2. Elongation at break of kenaf bast-filled foam *versus* filler content and comparison between untreated and treated kenaf bast/NRLF

The trend of modulus at 100% elongation (M100) *versus* filler content for kenaf bast/NRLF can be seen in Fig. 3. Modulus (M100) increased linearly with increment of filler into the foam because of high rigidity. High loading of filler required high force to stretch specimens to the given percent of elongation (100%). Moreover, the viscosity of the matrix increased after the filler addition. A high viscous matrix will increase the amount of energy to cleave chain-chain and chain-filler attachments (Tugau 2010).

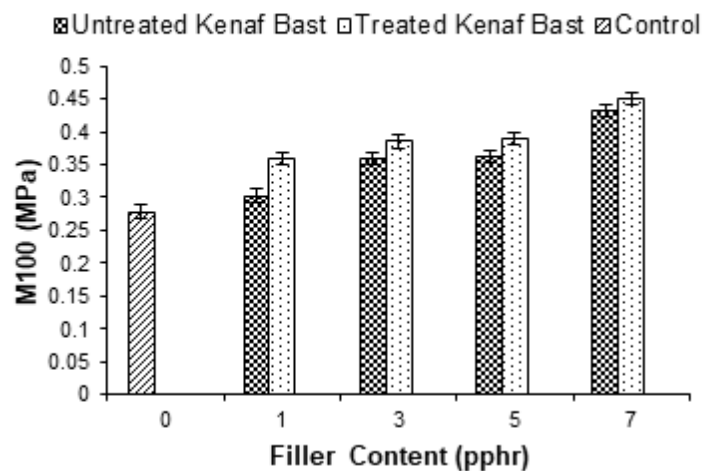


Fig. 3. Modulus at 100% elongation (M100) of kenaf bast-filled foam *versus* filler content and comparison between untreated and treated kenaf bast/NRLF

Based on Fig. 3, M100 was higher with the addition of treated kenaf bast into NRLF compared to untreated kenaf bast foam. This is because of the reduction of incompatibility between fibers and rubber matrix by the silane coupling agent that resulted in better adhesion between the filler and matrix, thus increasing the rigidity (Cao *et al.* 2014). The formation of chemical bonding between fiber and NRL matrix through chemical reactions is illustrated in Fig. 4. Bis-(3-triethoxysilylpropyl) tetrasulphane (Si-69) contains ethoxy hydrolysable groups at both ends that enable the silicon groups to bond with kenaf fibres and the tetrasulphane group of its centre will bond with natural rubber latex matrix.

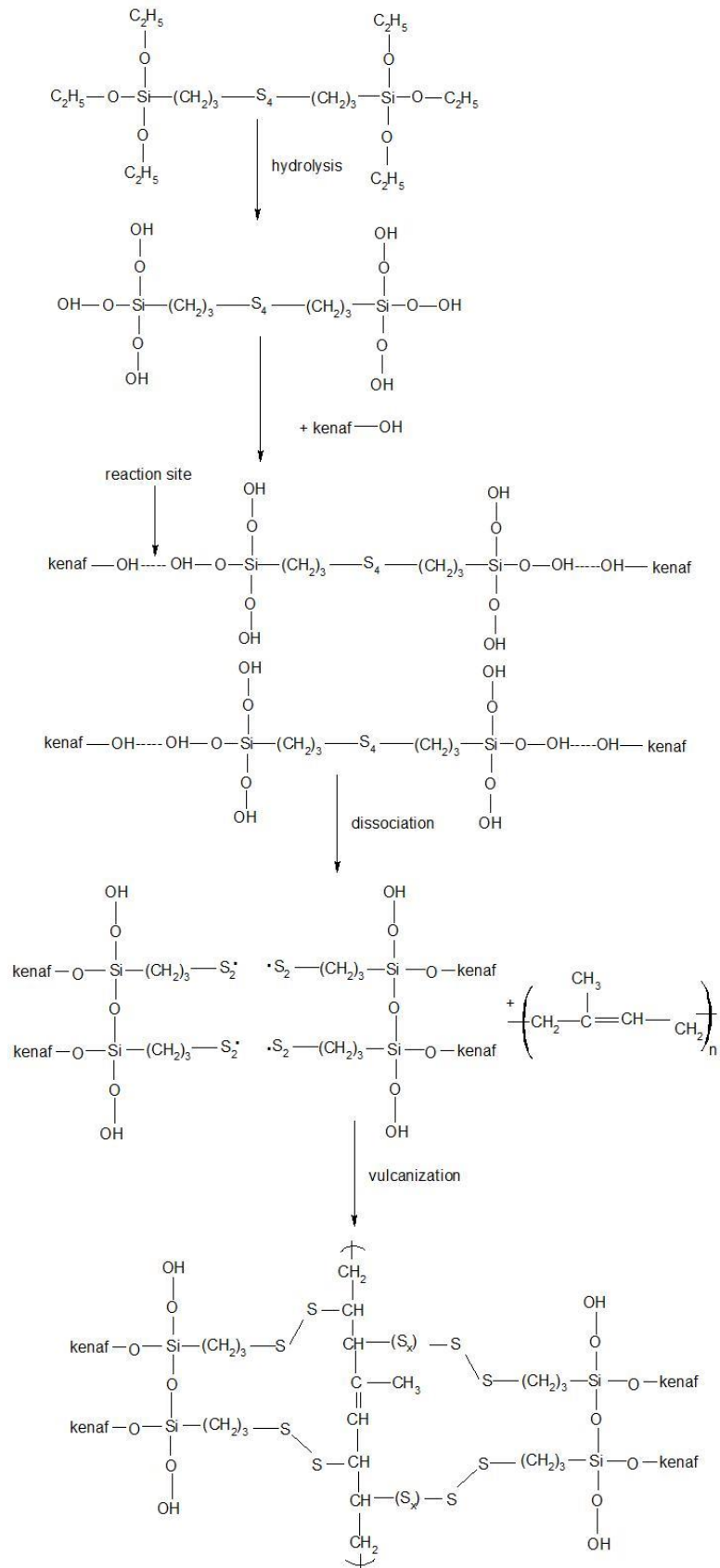


Fig. 4. Possible reaction between silane coupling agent (Si-69) with kenaf bast and NR

Kenaf fibres has OH groups on their surface, which have the potential to be the reactive sites. Thus, natural rubber latex interaction with kenaf will be improved by using Si-69 (Kхими and Pickering 2016). As a result, a solid interfacial layer was greatly enhanced between the two phases. Kenaf fiber was tightly cross-linked between the two phases, thus increasing the stiffness of the treated samples. Figure 4 shows the possible reaction between the silane coupling agent (Si-69) with kenaf bast and NR.

Compression Test

Figure 5 exhibits the compression test at 50% strain values *versus* the loading of kenaf bast. The values of stress increased as the filler loadings increased. Higher filler loading required a higher amount of force for compression at 50% strain of kenaf bast-filled foams. As a result, higher stiffness of the foams was produced. At the same filler loadings, the values of stress of treated and untreated kenaf bast/NRLF was compared. Again, due to better rubber-filler adhesion, treated kenaf bast foam showed higher stress values compared to untreated kenaf bast-filled foam.

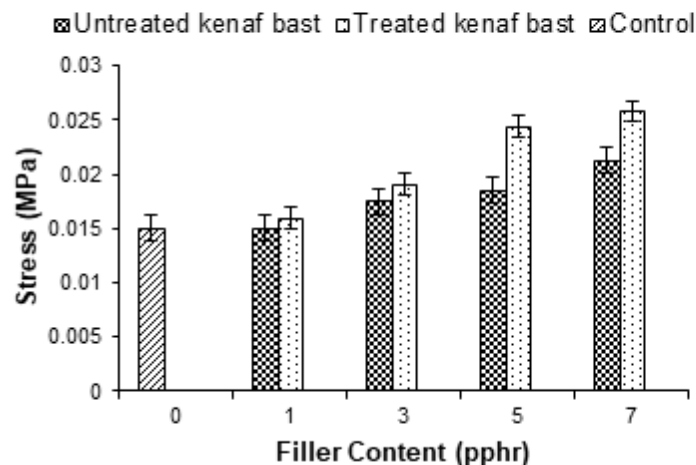


Fig. 5. Compression test at 50% strain of kenaf bast-filled foam *versus* filler content and comparison between untreated and treated kenaf bast/NRLF

Hardness

Hardness of the kenaf bast/NRLF at different filler loadings is shown in Fig. 6. The hardness value for all foam samples was within a range of 70 to 85, which is in the range of R34-Firm (Bashir *et al.* 2017). Based on Fig. 6, higher kenaf loadings resulted in increases of hardness. Higher kenaf loadings caused the filler to form aggregates, which constrained the mobilization of filler in NRLF and led to the decreasing of flexibility and elasticity of rubber chain. Thus, the stiffness of the NRLF increased resulting from increment of hardness.

The results also showed higher values of hardness for treated-kenaf bast/NRLF than untreated-kenaf bast/NRLF. Silane treatment on kenaf surfaces did improve hardness of composite due to better interfacial adhesion between the fiber and matrix polymer. Using the silane coupling agent, the chemical reaction took place and connected the chains. The rubbery matrix became less elastic and more rigid. Thus, high resistance to elastic deformation surface occurred. The result obtained agreed with previous work by Nishitani *et al.* (2017), who reported higher hardness value of treated hemp fiber (HF) reinforced plant-derived polyamide 1010 (PA1010) biomass composite compared with the untreated sample.

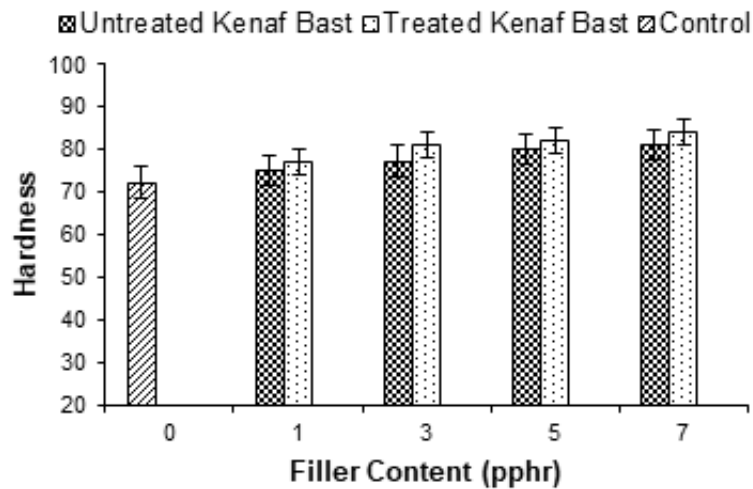


Fig. 6. Hardness of kenaf bast-filled foam *versus* filler content and comparison between untreated and treated kenaf bast/NRLF.

Swelling

The trend of swelling percentage of kenaf bast-filled foams at different filler content is shown in Fig. 7. Swelling percentage was decreased for both treated and untreated kenaf bast-filled NRLF with increment of kenaf loading due to high volume-fraction of filler. This is because filler particles can act as obstacles for penetration of toluene into the rubber matrix. As shown, swelling percentage of treated samples resulted in lower value compared with untreated samples. This is because of more crosslinking structure formed led to reduction the free spaces for toluene to penetrate into the foam. The same observation was reported by Ho *et al.* (2015); EVA/NR/PF_{silane} composites showed lower mass swell percentage in comparison with EVA/NR/PF composites as free volume for toluene to penetrate were limited.

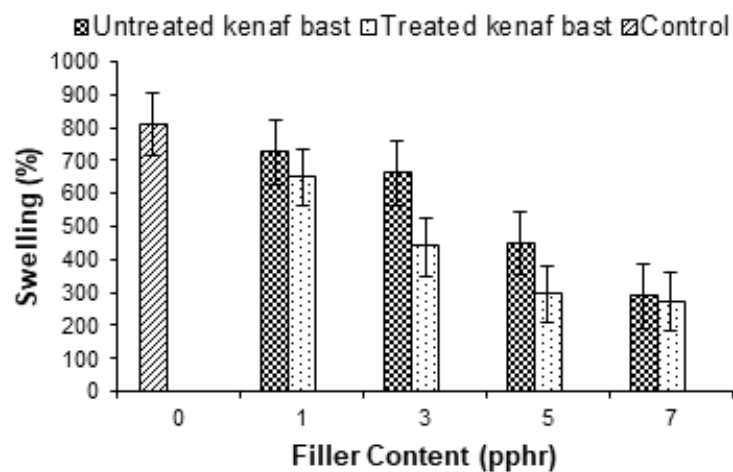


Fig. 7. Swelling percentage of kenaf bast-filled foam *versus* filler content and comparison between untreated and treated kenaf bast/NRLF.

Compression Set

Figure 8 shows recovery percentage for both treated and untreated kenaf bast-filled foams *versus* the loading of kenaf bast. The results showed a decrease of recovery percentage with an increase of kenaf loading for both treated and untreated kenaf bast-filled NRLF due to a more broken molecular chain. The recovery percentage value after addition of filler at 1 pphr was lower than the control sample. This shows that the foam was better to resist permanent deformation after prolonged compressive stresses at a given temperature and deflection with the help of filler due to high stiffness.

However, small differences in recovery percentage between treated and untreated samples can be seen in Fig. 8. Treated samples show small difference of values in recovery percentage (82.52%, 81.23%, 81.2%, and 80.52%) compared to untreated samples (82.64%, 81.52%, 81.43%, and 80.99%) at the same filler loading. This observation indicated that silane treatment of kenaf did not affect the compression set of kenaf bast-filled NRLF.

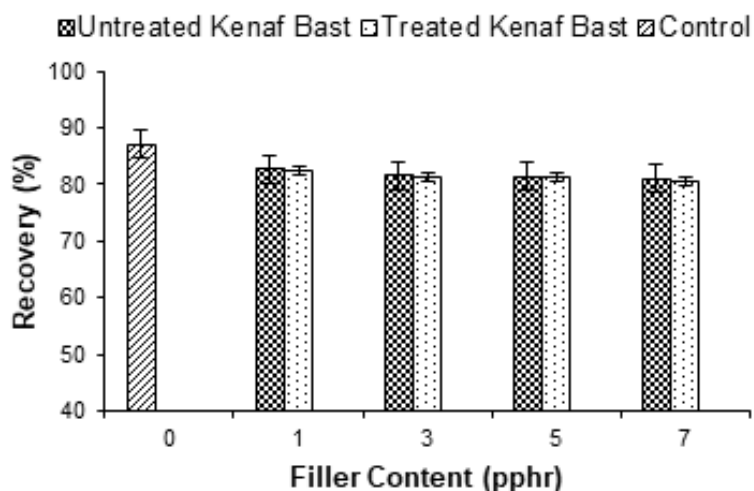


Fig. 8. Recovery percentage for both treated and untreated kenaf bast/NRLF *versus* filler content

FTIR Analysis

The results of FTIR analysis of both treated and untreated kenaf bast/NRLF are depicted in Fig. 9 to determine the presence of the silanol group and the stretching of peaks due to the silane treatment. Figure 9(a) represents the untreated kenaf bast/NRLF, while Fig. 9(b) represents the silane-treated kenaf bast/NRLF.

Formation of broad bands within the range of 3300 to 3500 cm^{-1} represented O-H stretching of Si-OH. An absorption peak can be detected at 1017 cm^{-1} , attributed to Si-O stretching of Si-OH (Xu *et al.* 2007). Other characteristic peaks were found in the range of 2800 to 3000 cm^{-1} for both treated and untreated kenaf bast/NRLF, which can be attributed to aliphatic alkyl group (C-H) stretching of $-\text{CH}_2$ (Xu *et al.* 2007). However, the infrared band at 2855 cm^{-1} increased in intensity for the treated sample (2925 cm^{-1}), which indicated improvement of reaction as increasing in chain length (Coates 2006). Thus, better interaction between kenaf filler and the rubber matrix by silane treatment can be demonstrated from the formation of these bonds.

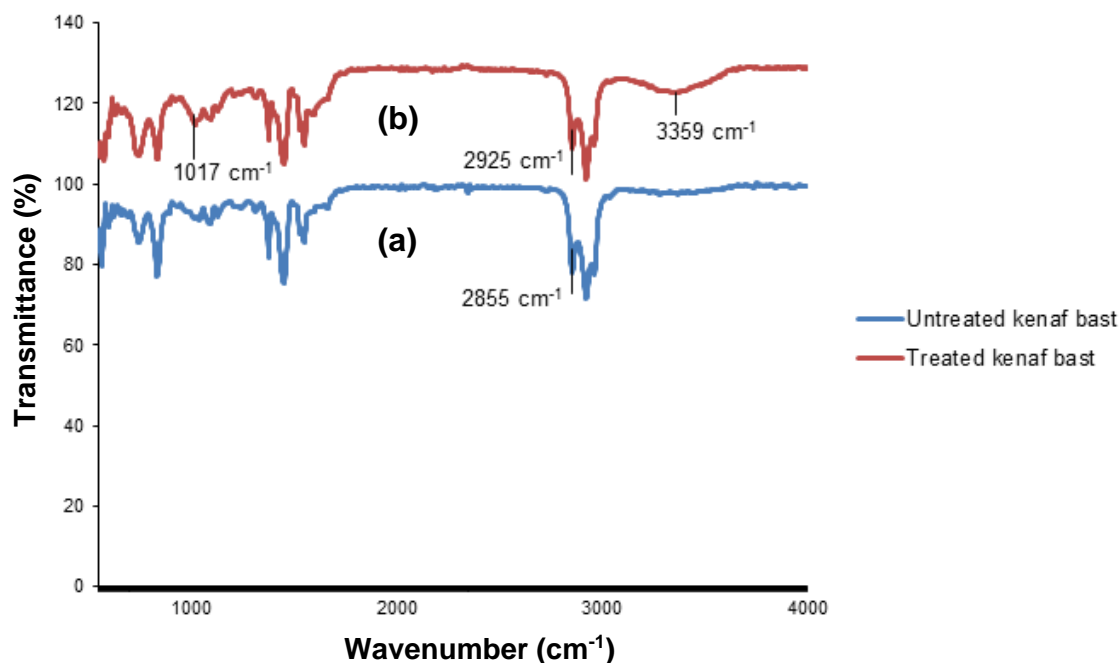


Fig. 9. FTIR spectrum kenaf bast/NRLF: (a) without silane treatment and (b) with silane treatment at 7 pphr of kenaf bast/NRLF

Surface Morphology Study

Figure 10 represents the influence of treated kenaf incorporation on morphologies of kenaf bast/NRLF. From Fig. 10a and Fig. 10b, both samples clearly show open cell structures.

A similar observation was reported by Roslim *et al.* (2012), who found that foam structure is made of continuous interconnecting open cells, based on SEM imaging. When a comparison is made, it can be seen that the sample with treated kenaf (Fig. 10b) showed small pores and stable sizes (170 μm , 184 μm and 187 μm) of cell structures compared with the sample with untreated kenaf (Fig. 10a) with measurements 137 μm , 226 μm and 285 μm . This showed that the addition of treated kenaf to the system reduced the pore size and gave better cell structures to the latex foam.

Filler-matrix interaction of untreated and treated kenaf bast/NRLF at 7 pphr kenaf loading was observed in Fig. 10c and Fig. 10d. From Fig. 10c it can be seen that the sample with untreated kenaf showed that a gap was built between the filler and matrix, thus indicating weak filler-matrix interaction. By contrast, the sample with treated kenaf in Fig. 10(d) showed better filler-matrix interaction, which led to the improvement in tensile properties.

This observation demonstrated the higher tensile strength of treated samples that was discussed earlier. In Fig. 10e, filler agglomeration can be spotted in several places at 7 pphr kenaf loading which support result of tensile strength that decreased as filler loading increased.

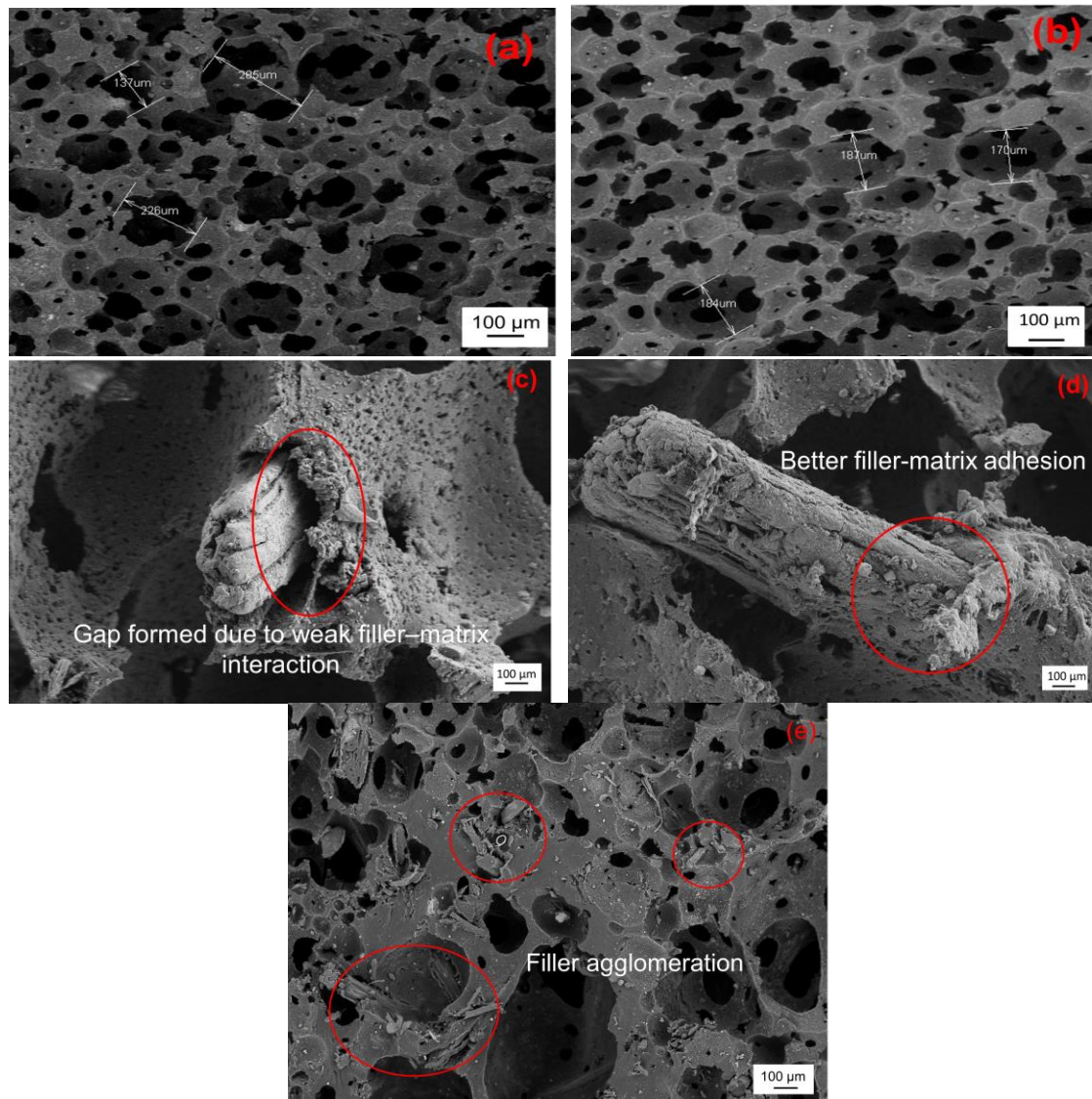


Fig. 10. (a) Untreated kenaf bast/NRLF at 100x magnification, (b) treated kenaf bast/NRLF at 100x magnification, (c) untreated kenaf bast/NRLF at 7 pphr of 500x magnification, (d) treated kenaf bast/NRLF at 7 pphr of 500x magnification, and (e) filler agglomeration at 7 pphr of kenaf bast/NRLF at 120x magnification

CONCLUSIONS

1. Kenaf bast loading had the greatest influence on modulus at 100% elongation (M100), compression strength, and hardness. Increasing kenaf bast loading increased M100, compression strength, and hardness values.
2. However, tensile strength, elongation at break, and the swelling and recovery percentages decreased as the kenaf bast loading increased.
3. For the effect of silane treatment on properties of natural rubber latex foam (NRLF), treated NRLF showed higher value in tensile strength, hardness, and compression

strength compared to untreated NRLF. The reverse effect was shown for elongation at break, swelling and recovery percentage.

4. Better contact at filler-matrix interfaces was apparent from SEM images, which is consistent with improved adhesion of treated NRLF to the matrix.
5. The presence of the silanol group and stretching peaks due to silane treatment was obtained by FTIR analysis.

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