Middle-East Journal of Scientific Research 24 (9): 2685-2692, 2016
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2016.24.09.23930

Effect of Chemical Treatment on Kenaf Single Fiber and Bio-Phenolic Resin Regarding its Tensile and Interfacial Shear Stress

[1]Zahra Dashtizadeh, [1,23]K. Abdan, [1]M. Jawaid, [1]Mohd Asim Khan, [4]Mohammad Behmanesh, [5]Masoud Dashtizadeh, [6]Cardona Francisco and [7]M. Ishak

[1]Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products (INTROP), University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[2]Aerospace Manufacturing Research Centre, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[3]Aerospace Malaysia Innovation Centre, Cyberjaya, Malaysia.
[4]Department of Mechanical Engineering, University Putra Malaysia, 43400 Serdang, Malaysia.
[5]Department of Civil Engineering, Islamic Azad University of Gorgan, Iran
[6]Aerospace Manufacturing Research Center (AMRC), Faculty of Engineering, University Putra Malaysia
[7]Department of Aerospace Engineering, University Putra Malaysia

Abstract: Since the rise of environmental issues, researchers were interested in natural fibers to replace artificial fibers in composites. Kenaf is a natural fiber which has shown significant high mechanical properties, however many researchers indicate that alkaline or silane treatment can improve the fiber mechanical properties. In this paper, the effect of alkaline and silane treatment on kenaf single fiber is studied as well as the treatment effect on interfacial shear strength between kenaf single fiber and bio-phenolic resin derived from cashewnut waste industry. The results determine that 2% alkaline treatment for 4hrs can improve the tensile strength significantly. Alkali treatment of the kenaf fiber increase the interfacial shear strength. Morphological study indicate that long term of chemical treatment damages the kenaf fiber.

Key words: Chemical Treatment · FTIR · Kenaf · Mechanical Properties · Micro-droplet Test

INTRODUCTION

Natural fibers were introduced for industrial applications due to their biodegradability property, cheapness and availability as well as having reasonably good mechanical properties. Besides their light weight reduces the fuel cost in automotive and aerospace industries. However, their hydrophilic nature reduces the compatibility between the natural fibers and different resins such as epoxy, polyester and etc. To reduce the hydrophilicity of the natural fibersand, as a result, to increase the compatibility of the natural fibers with different resins, chemical treatments were introduced.

While many researchers have reported on theimprovement of mechanical and thermal properties of natural fibers by chemical treatments [1, 2], still there is no specific and quantitative report on the durability enhancement, moisture absorbency and toughness by chemical treatment [3, 4].

One of the most common treatment is alkaline treatment or mercerization which according to the Eq. 1 removes the wax, lignin and hemicellulos of the fiber to increase the surface roughness so then the interfacial bonding between the fiber and the resin would increase, besides since mostly cellulose remains after treatment in the fiber, therefore the number of bonds between cellulose and the resin increases too [5].

$$\text{Fiber-OH} + NaOH = \text{Fiber-}O^{-}Na^{+} + H_2O \quad \text{Eq.1}$$

Study of alkaline and acrylic acid treatment on rice husk and jute mat indicates that the moisture absorption

Corresponding Author: K. Abdan, Department of Biological and Agricultural Engineering, Faculty of Engineering, University Putra Malaysia, 43400, Serdang, Selangor, Malaysia.

of the fibers decreases with acrylic acid while the flexural property of the fibers and unsaturated polyester composite increase with alkaline treatment [6].

Besides it has been reported that the chemical treatment in most casesis not environment-friendly, however, sodium bicarbonate as an environment-friendly agent has been studied to investigate its effect on sisal fibers to determine the 120h as the optimum duration of treatment. The aforementioned treatment enhances the mechanical properties as well as the interfacial bonding with epoxy resin [7]. In addition, alkaline and silane treatment on sisal fiber also results in decrement of tensile strength and modulus as a result of removing the non-cellulosic fibers and causing voids in the fibers, however, the mechanical properties of the composites with treated fibers showed improvement compared to untreated fibers due to better interfacial bonding of the sisal fibers and resin [8].

Also, jute fiber treatment with alkaline and bleach determined that crystal changing in the fiber depends on the treatment procedure [9]. Coir and palm fiber under alkaline and or bleaching treatment determine that removing impurities increases the interfacial shear strength that is a result of better interfacial bonding between fiber and resin. However, palm fiber showed a better interfacial shear strength compared to coir [8-10]. For flax fiber the alkaline treatment determined a great increment on thein-plane permeability of the non-woven mat [11].

In addition, to the above, kenaf is specifically studied for different types of treatment rather than only alkaline or silane treatment. A combination of alkaline treatment and aluminum hydroxide impregnation on kenaf fiber under the experiment conditions, determined a significant improvement on water absorption characteristic of the natural fiber, while improving tensile strength as well as Young's modulus which make the kenaf fiber highly potential for replacement of glass fiber especially in automotive industry [12]. Considering different treatment duration, kenaf fibers were immersed in 6% w/v alkaline for 48 h and 144 h, the mechanical properties improved with the treatment and for modulus of storage and loss, only above the glass transition temperature, the chemical treatment effects [13].

Also, 3 alkali concentration was considered for kenaf fiber to investigate the optimum NaOH concentration for tensile strength. 3%, 6% and 9% of NaOH treatment for 24 h were performed. The tensile results indicate that 6% alkali treatment imparts the highest strength, also adding MAPE and MAPP as coupling agent would significantly improve the strength [14].Although 10% and 15% alkali concentration determined more brittleness compared to row fibers and, therefore, these concentrations damaged the fibers [15]. Even for hybrid composites of kenaf and other fibers such as Kevlar, alkali treated kenaf fibers improved the mechanical properties [16]. In contrast with all the above experimental researches, it has been reported that for kenaf/ thermoplastic polyurethane composite, with increment in alkali concentration percentages , 0% (untreated), 2%, 4% and 6%, the mechanical properties such as tensile, flexural and impact strength decrease, while the morphology of the composites improve. Even for TGA results, it shows a decrement in thermal stability by NaOH treatment. This may happen due to the amorphous behavior of the above composites [17].

Another interesting treatment agent for kenaf fiber is rice-washed water. Kenaf fibers treated with rice-washed water have higher mechanical properties as well as thermal stability due to theincrement of hydrophilicity behavior of the kenaf fibers [18]. Not only different chemical concentration or treatment duration was studied, but also, the treatment in different temperature was experimented. 100°C, 130°C and 150°C were the different temperatures in which the 3% NaOH concentration treatment was performed. The modulus of elasticity increased up to 130°C and then decreased for 150°C. Also internal bonding increased with the treatment [19].

According to previous studies, treatment parameters, such as chemical concentration and duration plays animportant role in the obtained results [20].

In this paper, the effect of alkaline and silane treatment for kenaf single fiber on its mechanical properties has been studied. Besides the interfacial shear strength of kenaf and cardanol resin was investigated.

MATERIALS AND METHODS

Materials: Kenaf fiber was provided from the laboratory of biocomposites, Institute of Tropical Forestry and Forest Products (INTROP), University Putra Malaysia (UPM) in a bundle form which was required to be cleaned and comb properly before use. NaOH (Sodium Hydroxide) and Silane for treatment were purchased from Jasa Sejiwa Enterprise, Malaysia and cardanol was purchased from Chemovate Company, India.

Table 1: Chemical concentration and duration

	NaOH				Silane			
	2%	6%	12%	18%	2%	6%	12%	18%
Class 1	2hr	2hr	2hr	2hr	2hr	2hr	2hr	2hr
Class 2	4hr	4hr	4hr	4hr	4hr	4hr	4hr	4hr

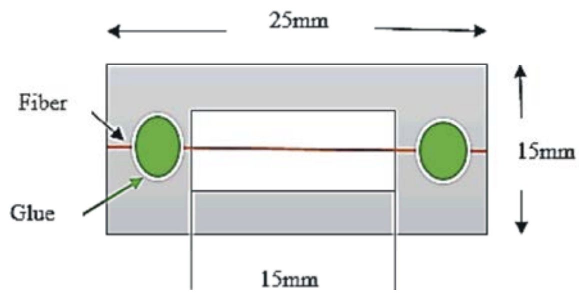


Fig. 1: Paper Frame for Tensile test

Methodology: Four chemical concentration was decided based on literature to cover from a big range of chemical concentration treatment, 2%, 6%, 12% and 18% of NaOH and Silane were used separately for kenaf fiber treatment. In addition 2 different duration for chemical treatment was considered in order to have the best effect of the chemical on the fibers as well as minimizing the drawbacks of the treatment such as damaging the fiber by removing cellulosic contents. Due to this reason, the fibers were treated for 2hrs and 4hrs to compare the results as well. The Table 1 summarizes the chemical concentration and duration.

First the fibers were cleaned and combed to remove any visible impurity. After that the kenaf fibers were soaked in the solution of the chemical and distilled water for the constant duration of 2hrs for class 1 and 4hrs for class 2. In order to prepare the solution, weight percentage was considered for instance 2% NaOH means that in 100g of thesolution, 2g is NaOH and 98g is distilled water. Then for each class, after the duration was passed, the fibers were well rinsed off with distilled water to reach the neutral PHand put in the ambient temperature to drain. In order to dry them properly, after 24hrs, the fibers were put into the oven at 103°C for 8hrs. The samples were then ready for testing.

Tensile Test: Tensile test was performed according to ASTM C155703 (2008) standard. A paper frame for the tensile test was required that is shown in the Fig. 1.

The single fiber was glued to the paper frame then after drying the tensile test was performed using a 5kN Instron 3365 Universal testing machine with a constant speed of cross head displacement of 500×10^{-6} m/min.

Micro Droplet Test: Micro-droplet testing was performed to determine the interfacial shear strength between kenaf fiber and cardanol resin that is a form of natural phenolic resin derived from cashew nut shell. The same standard of tensile testing was followed for the micro-droplet testing.

A single fiber was attached to the paper frame with glue. Then a drop of cardanol resin was put in the middle of the gauge at the center of the fiber length by a 5kN Instron 3365 Universal testing machine. After the drop was cured for 24hr, then the test was performed using the following equation [21].

$$\tau = \frac{F}{\pi DL} \qquad \text{Eq. 2}$$

where τ is interfacial shear stress (MPa), F is load at the maximum stress (N), D is the single fiber diameter (m) and L is embedded length (m).

FTIR: The FTIR test was performed on all the samples to investigate the effect of the treatment on different chemical groups that exist in the kenaf fiber by the Spectrum 100 FTIR machine.

SEM: Scanning electron microscopy (SEM) of the fibers with different treatment was done to determine the surface and inner treatment effect on the fibers. The fibers were gold coated before putting in the HITACHI S-3400 instrument for SEM. The test was performed with an emission current of 60µA and 5.0kV of voltage.

RESULTS

Tensile Properties: The tensile strength at yield are presented in the Fig. 2.

Interfacial Shear Strength Properties: The interfacial shear strength and modulus are presented in the Figs. 3 and 4 below:

FTIR Results: The results of FTIR is demonstrated in the Figs. 5 and 6 below:

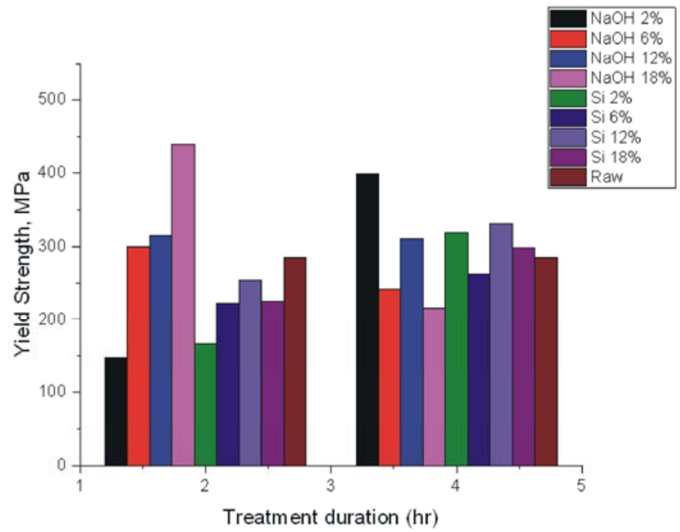


Fig. 2: Mean yield strength driven from tensile test

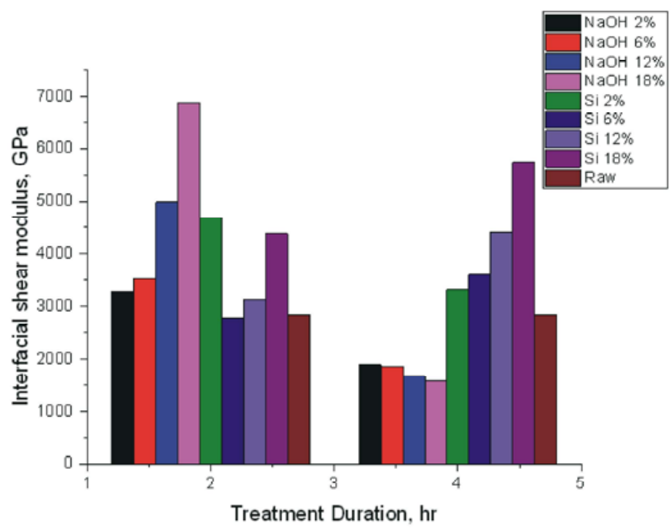


Fig. 3: Interfacial shear modulus driven from micro-droplet test

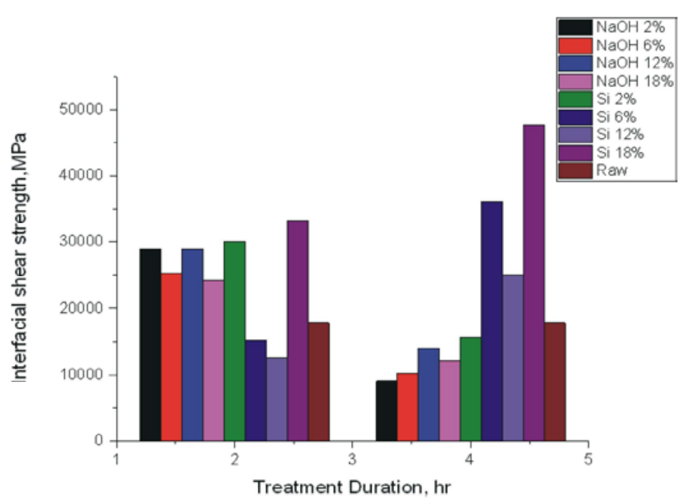


Fig. 4: Interfacial shear strength

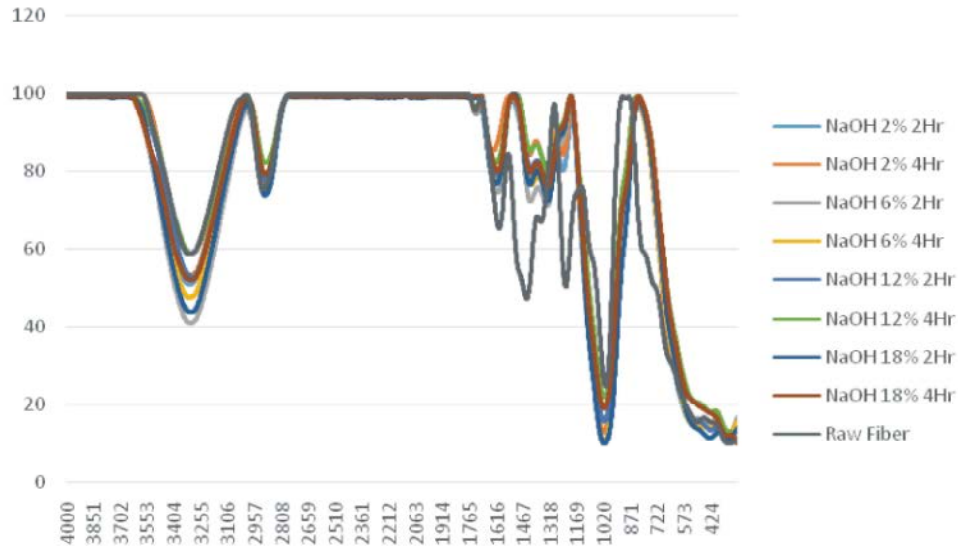


Fig. 5: FTIR of NaOH treatment fibers

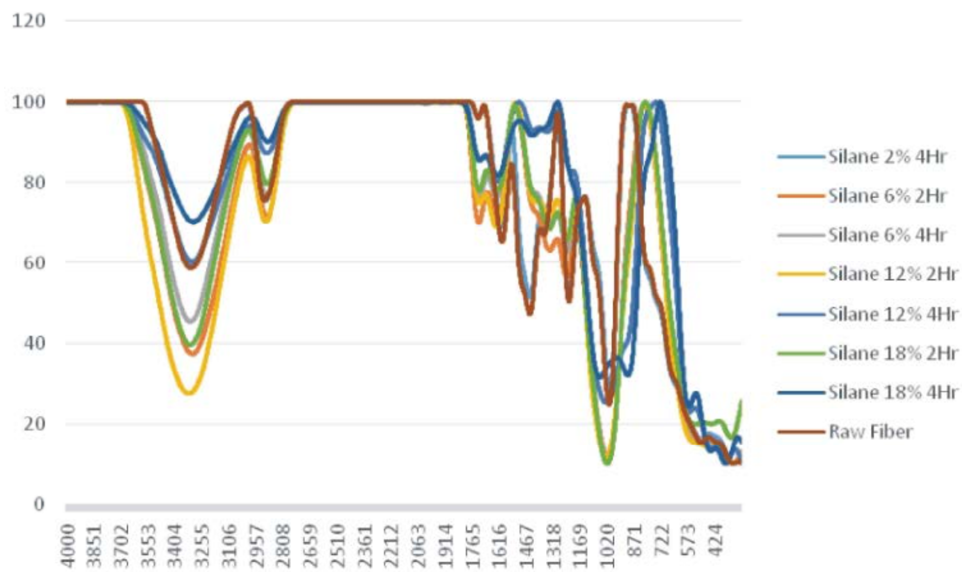


Fig. 6: FTIR results of silane treatment fibers

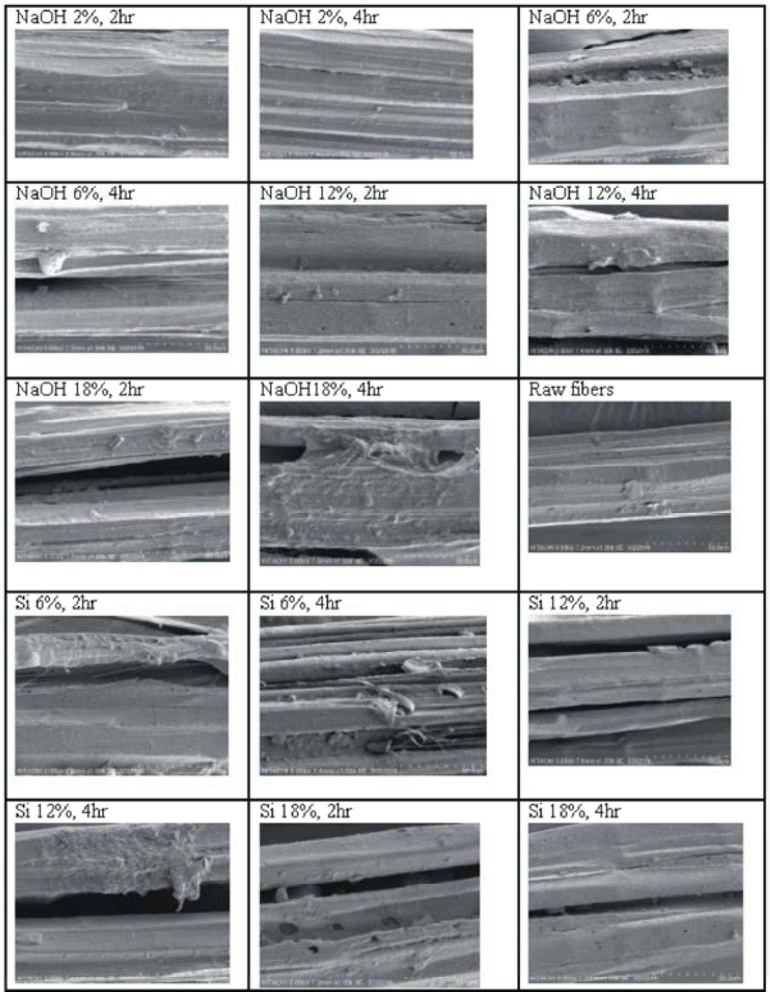
SEM rResults: SEM images of the samples are presented in Table 2.

DISCUSSION

The above Figures indicate that 2hrs of chemical treatment is not effective unless for the 18% NaOH concentration. For Silane treatment 2hrs definitely is not efficient because from the tensile results for all concentrations the tensile results are less than the one for untreated or raw fiber. However only for 18% NaOH, there is a significant improvement in tensile strength for yield strength.

According to the above figures, 4hrs for silane treatment improved the tensile yield strength for all concentrations, however, 2% NaOH treatment illustrates a significant improvement in tensile strength. The improvement of the tensile strength after chemical treatment is due to removing the impurities from the fibers which weaken it. For micro-droplet test, the Figs. 3 and 4 indicate that the 2hrs of treatment for all NaOH concentration is almost successful, because the interfacial shear strength and modulus increased. While for silane treatment requires 4hrs to show a significant increment in interfacial shear stress and modulus. However, 4hrs of treatment for NaOH shows decrease in the interfacial shear stress that is due

Table 2: SEM images of the kenaf fibers



to weakened bonding after treatment. It can be seen clearly that duration of the treatment is an important criterion for natural fiber treatment. Since the same concentration of NaOH for 2hr improve the bonding whilst for 4hrs decreases. Because if the fiber is treated for very long time all the impurities and lignin of the fiber would be removed that would weaken the bonding between the fiber and the resin.

FTIR results indicate that treatment will increase the hydroxyl group in the functional components except for silane 12% and 18% for 4hrs. While C-H group reduces by treatment for most of the treatment classes except for silane 12% 2hr and 4hr and NaOH 18% 4hrs. Treatment with NaOH and silane will decrease the aliphatic group, while it does not have much effect on N-containing groups.

In complete agreement with the mechanical results, the SEM images determine that the higher concentration of the chemical for both alkaline and silane damages kenaf single fibers by small crack on the surface of the fibers. In addition, the damage is more severe for longer time of treatments. Also, all the chemical cannot be removed from the fibers even with several water washing, which may cause even more weakness for the fiber.

CONCLUSION

Kenaf single fibers were treated with alkaline and silane with a wide range of concentration and for two different treatment durations, 2hrs and 4hrs. The results indicate that, chemical treatment with high concentration as 12% and 18% damage the fiber by removing not only the impurities but also the lignin, therefore the bonding between the kenaf fiber and bio-phenolic (cardanol) decreases. Form the results of this experiment, 2%NaOH for 4hrs is recommended for kenaf single fiber as reinforcement of bio-Phenolic (cardanol).

ACKNOWLEDGEMENT

The authors would like to thank MOSTI Grant (Vote No.: 5450760) for supporting this research experiment and all the very kind and helpful staff of Institute of Tropical Forestry and Forest Products (INTROP), University Putra Malaysia (UPM).

REFERENCES

1. Li, X., L.G. Tabil and S. Panigrahi, 2007.Chemical Treatments of Natural Fiber for Use in Natural Fiber-Reinforced Composites: A Review. J Polym Environ, 15: 25-33.
2. Lai, S.M., Y.H. Kao, Y.K. Liu and F.C. Chiu, 2016. Preparation and properties of luffa fiber- and kenaf fiber-filled poly(butylene succinate-co-lactate)/starch blend-based biocomposites. Polymer Testing, 50: 191-199
3. Saha, P., S. Chowdhury, D. Roy, B. Adhikari, J.K. Kim and S. Thomas, 2016. A brief review on the chemical modifications of lignocellulosic fibers for durable engineering composites.Polym. Bull, 73: 587-620.
4. Al-Oqla, F.M., O.Y. Alothman, M. Jawaid, S.M. Sapuan and M.H. Es-Saheb, 2014. Processing and Properties of Date Palm Fibers and Its Composites, Biomass and Bioenergy, Processing and Properties. Springer International Publishing Switzerland, pp: 1-25.
5. Mahjoub, R., J.M. Yatim, A.R.M. Sam and M. Raftari, 2014. Characteristics of continuous unidirectional kenaf fiber reinforced epoxy composites. Materials & Design, 64: 640-649.
6. Chanda, A.K., A. Hazra, M.P. Kumar, S. Neogi and Swati Neogi, 2015. Chemical Treatments of Rice Husk Filler and Jute Fiber for the Use in Green Composites. Fibers and Polymers, 16(4): 902-910.
7. Fiore, V., T. Scalici, F. Nicoletti, G. Vitale, M. Prestipino and A. Valenza, 2016. A new eco-friendly chemical treatment of natural fibres: Effect of sodium bicarbonate on properties of sisal fibre and its epoxy composites. Composites Part B: Engineering, 85: 150-160
8. Orue, A., A. Jauregi, U. Unsuain, J. Labidi, A. Eceiza and A. Arbelaiz, 2016. The effect ofalkaline and silane treatments on mechanical properties and breakage of sisal fibers and poly(lactic acid)/sisal fiber composites. Composites: Part A, 84: 186-195.
9. Wang, W.M., Z.S. Cai, J.Y. Yu and Z.P. Xia, 2009. Changes in Composition, Structure and Properties of Jute Fibers after Chemical Treatments. Fibers and Polymers, 10: 776-780.
10. Chollakup, R., W. Smitthipong, W. Kongtud and R. Tantatherdtam, 2013. Polyethylene green composites reinforced with cellulose fibers (coir and palm fibers): effect of fiber surface treatment and fiber content. Journal of Adhesion Science and Technology, 27(12): 1290-1300.
11. Xue, D. and M. Miao, 2012. Influences of moisture absorption and chemical treatments on the resin flow characteristics of natural fibre nonwoven mats. The Journal of the Textile Institute, 103(9): 1024-1030.
12. Xia, C., S. Zhang, S.Q. Shi, L. Cai and J. Huang, 2016. Property enhancement of kenaf fiber reinforced composites by in situ aluminum hydroxide impregnation. Industrial Crops and Products, 79: 131-136
13. Fiore, V., G. Di Bella and A. Valenza, 2015. The effect of alkaline treatment on mechanical properties of kenaf fibers and their epoxy composites. Composites Part B: Engineering, 68: 14-21.
14. Meon, M.S., M.F. Othman, H. Husain, M.F. Remeli and M.S.M Syawal, Improving Tensile Properties of Kenaf Fibers Treated with Sodium Hydroxide. Procedia Engineering, 41: 1587-1592.
15. Mahjoub, R., J.M. Yatim, A.R.M. Sam and S.H. Hashemi, 2014. Tensile properties of kenaf fiber due to various conditions of chemical fiber surface modifications. Construction and Building Materials, 55: 103-113.
16. Yahaya, R., S.M. Sapuan, M. Jawaid, Z. Leman and E.S. Zainudin, 2015. Effect of layering sequence and chemical treatment on the mechanical properties of woven kenaf–aramid hybrid laminated composites. Materials and Design, 67: 173-179.
17. El-Shekeil, Y.A., S.M. Sapuan, A. Khalina, E.S. Zainudin and O.M. Al-Shuja'a, 2012. Effect of alkali treatment on mechanical and thermal properties of Kenaf fiber-reinforced thermoplastic polyurethane composite, Journal of Thermal Analysis and Calorimetry, 109(3): 1435-1443.
18. Park, J.M., J.Y. Choi, Z.J. Wang, D.J. Kwon, P.S. Shin, S.O. Moon and K.L. De Vries, 2015. Comparison of mechanical and interfacial properties of kenaf fiber before and after rice-washed water treatment. Composites Part B: Engineering, 83: 21-26.

19. Taib, M.N.A.M., M.A. Jamaludin and M.A. Kassim, 2015. Effects on Physical and Mechanical Properties of Thermochemical Treated Kenaf (*Hibiscus Cannabinus*) Fibres Composite Board. Industrial Engineering, Management Science and Applications, 349: 657-664.
20. Qaiss, A.E.K., R. Bouhfid and H. Essabir, 2014. Natural Fibers Reinforced Polymeric Matrix:Thermal, Mechanical and Interfacial Properties. Biomass and Bioenergy: Processing and Properties Springer International Publishing Switzerland, pp: 225-245.
21. Shito, T., K. Okubo and T. Fujii, 2002. Development of Eco-Composites Using Natural Bamboo Fibers and Their Mechanical Properties. High Performance Structures and Composites, pp: 175-182.