

## EFFECT OF PINEAPPLE LEAF FIBER LOADING ON THE MECHANICAL PROPERTIES OF PINEAPPLE LEAF FIBER – POLYPROPYLENE COMPOSITE

Ayu Natasya Kasim<sup>a,b\*</sup>, Mohd Zulkefli Selamat<sup>a,b</sup>, Nabila Aznan<sup>b</sup>, Siti Norbaya Sahadan<sup>a,b</sup>, Mohd Ahadlin Mohd Daud<sup>a,b</sup>, Ridhwan Jumaidin<sup>a,b</sup>, Suhaila Salleh<sup>a,b</sup>

<sup>a</sup>Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

<sup>b</sup>Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

### Article history

Received

15 May 2015

Received in revised form

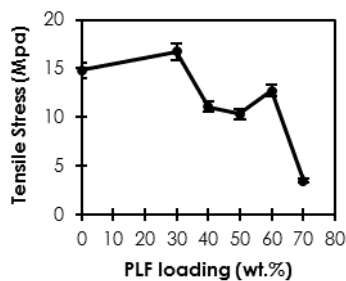
12 September 2015

Accepted

30 September 2015

\*Corresponding author  
ayunatasyakasim@yahoo.com

### Graphical abstract



### Abstract

Natural fibers have become an important issue in the development of fiber reinforced polymer (FRP) composite to resolve the current ecological and environmental problems. Among the many types of natural fibers that are available, pineapple leaf fiber (PLF) was selected as the natural fiber used in this study due to comparatively better mechanical properties, ease of availability and low cost. In this work, the effects of pineapple leaf fiber (PLF) loading on the properties of PLF/polypropylene (PP) composites was studied. The sample of composites was fabricated with five different fiber loading of PLF (30, 40, 50, 60 and 70 wt.%). An alkaline treatment was conducted to enhance the PLF properties. The fabrication was made by compression molding technique with random orientation of PLF. From the experimental study, the results revealed that the voids percentage and interfacial bonding between the PLF and PP affected the mechanical properties of the PLF/PP composite. Based on the results of tensile stress, hardness and density, it can be concluded that the PLF/PP composite with the composition ratio of 30/70 wt.% has shown the best mechanical properties compared to other composition ratios (40/60, 50/50, 60/40 and 70/30 wt.%), which are 16.71 MPa, 62.83 Shore-D and 0.93 g/cm<sup>3</sup> respectively.

Keywords: Pineapple leaf fiber (PLF); polypropylene (PP); fiber reinforced polymer (FRP)

### Abstrak

Gentian asli telah menjadi suatu isu penting dalam pembangunan polimer bertetulang gentian (FRP) komposit bagi membantu menyelesaikan masalah-masalah semasa ekologi dan alam sekitar. Antara pelbagai jenis serat semulajadi yang boleh didapati, serat daun nenas (PLF) telah dipilih sebagai gentian semulajadi yang digunakan di dalam kajian ini kerana mempunyai sifat mekanikal yang lebih baik, kemudahan ketersediaan dan kos yang rendah. Dalam kajian ini, kesan beban gentian daun nenas (PLF) pada sifat-sifat komposit PLF/polipropilena (PP) telah dikaji. Sampel komposit difabrikasi dengan teknik pengacuan mampatan dengan orientasi rawak PLF. Lima komposisi PLF yang berbeza (30, 40, 50, 60 dan 70 wt.%). Rawatan alkali telah dijalankan untuk meningkatkan sifat-sifat PLF. Dari kajian eksperimen, keputusan menunjukkan bahawa peratusan lompang dan ikatan antara muka diantara PLF dan PP telah memberi kesan kepada sifat mekanikal komposit PLF/PP. Berdasarkan keputusan tegasan tegangan, kekerasan dan ketumpatan, dapat disimpulkan bahawa komposit PLF/PP dengan nisbah komposisi 30/70 wt.% telah menunjukkan sifat-sifat mekanikal yang terbaik berbanding dengan nisbah komposisi yang lain (40/60, 50/50, 60/40 and 70/30 wt.%), iaitu 16,71 MPa, 62,83 Shore-D dan 0,93 g / cm<sup>3</sup> masing-masing.

**Kata kunci:** Pineapple leaf fiber (PLF); polypropylene (PP); fiber reinforced polymer (FRP)

© 2015 Penerbit UTM Press. All rights reserved

## 1.0 INTRODUCTION

Biodegradable Fiber Reinforce Polymer (FRP) is becoming an important research in this decade as green composite materials. Pineapple leaf fiber (PLF) is one of the natural fiber which has huge potential to be used as reinforcing materials in green composite product. Natural fiber is an alternative to glass fiber in FRP composite materials industry, especially in automotive application. Natural fibers composite give a combination of excellent mechanical and dielectric properties, as well as contribute to environmental advantages such as recyclable, biodegradable and renewability [1-8].

Additionally, the use of natural fibers in composite materials industry can reduce environmental pollution and waste disposal problems, as well as address issues of ecological concern. Other than that, it also consumes less energy during production, have no health risk when inhaled, pose no abrasion to a machine and most importantly, has a big impact in reducing the consumption of petroleum resources [4 & 5]. Kongkeaw *et al.* in 2011 [9] stated that natural fibers may play an important role in developing

biodegradable composites to resolve the current ecological and environmental problems.

There are various types of fibers used today. Some of the fibers that have been used by researchers in the development of natural fiber composites includes bamboo [2], pineapple leaf [4, 5, 10, 11, & 12], bagasse, lantana-camara [7], coir [13], jute, sisal, kapok [14], coconut [15], oil palm fibers [16], wood [17] and rice husk [18]. In this study, the pineapple leaf fiber is used as a reinforce material and the matrix is used polypropylene.

Pineapple leaf fiber is one of the most attractive materials as a reinforcing natural fiber in FRP, and the mechanical properties of PLF are listed in Table 1. Mohamad *et al.* in 2009 [10], states that in Malaysia the pineapple industry is marketable. However, only the fruit is used while the leaf, which contains fiber, is usually burned or thrown away, adding to pollution and wastage of a good potential sources of fiber.

This study aims to investigate the effect of PLF loading with randomly orientation on the mechanical properties of PLF/PP composite and to explore the potential of this composite. The mechanical properties such as tensile stress, hardness, bulk density and microstructure are observed.

**Table 1** Properties of pineapple leaf fiber: [5]

Property	Value
Density (g/cm <sup>3</sup> )	1.526
Softening Point (°C)	104
Tensile Strength (MPa)	170
Young's Modulus (MPa)	6260
Specific Modulus (MPa)	4070
Elongation at Break (%)	3
Moisture regain (%)	12

## 2.0 EXPERIMENTAL

### 2.1 Polymer Matrix

Polypropylene was in powder form with the types of homopolymer. The PP density was 0.9 g/cm<sup>3</sup> and melt flow index of 14 g/10min from Lotte Chemical Titan was used as matrix is shown in Figure 1.

### 2.2 Reinforcing Materials

Pineapple leaves were collected from cultivation areas in Perak Darul Ridzuan, Malaysia. The leaf was chopped to a length of 100 mm and extracted with a milling machine. The extraction process was performed to get the fibers by feeding the chopped pineapple leaf into the milling machine. After the extraction process the fibers undergone an alkaline

treatment process with the aim of modifying the fiber surface.

Firstly, the fibers were soaked in 5% of the NaOH solution in water reservoir for 1 hour at room temperature. The 1% concentration of the HCL was used to neutralize the PLF. Thereafter, the fibers were rinsed several times with distilled water and then dried in air at room temperature for 48 hours. The PLF after the chemical treatment is shown in Figure 2. Vinod et al. in 2013 [5] stated that by undergoing the chemical treatments the mechanical properties of the fiber material can be improved. By undergoing the chemical treatments it can remove the moisture content and all the impurities, treat the fiber surface, stabilize the molecular orientation, as well as improve the adhesion between hydrophilic PLF and hydrophobic PP [2, 4, 19, 20].



Figure 1 Polypropylene



Figure 2 Pineapple leaf fibers

### 2.3 Preparation of Composites

The composites with 3 mm thickness were prepared with the different compositions using manual mixing technique and compression molded to form a sheet of composites. The temperature and pressure has been fixed at the elevated values. The composition of PLF/PP composite by weight percentage (wt.%) of the fiber/matrix is show in Table 2. The composite samples which have been fabricated, with the compound between PLF and PP, was then placed in a mold with random orientation of the fibers. The orientation of the fibers is shown in Figure 3. Following this, the mold was placed in hot press machine at a temperature of 185 °C and a pressure of 3.5 MPa in 5 minutes for pre heat process and another 10 minutes for compression process. After that, the mold undergoes the cooling process for 20 minutes. Composite sheet is removed from the mold and then cut for testing according ASTM standard by using Proxxon saw.



Figure 3 Orientation of the fibers

Table 2 Composition of PLF/PP composite

No of samples	PLF (wt.%)	PP (wt.%)
1	0	100
2	30	70
3	40	60
4	50	50
5	60	40
6	70	30

### 2.4 Mechanical testing

Tensile test was carried out using Instron Universal Testing Machine (Model 5585H) controlled by Bluehill 2 software according to ASTM D 3039. Hardness test was determined using Analogue Shore Scale "D" Durometer according to ASTM D2240. Density measurement was performed using Digital Electronic.

#### 2.4.1 Tensile Test

Tensile testing was carried out according to ASTM D 3039 and the specimens were 140 mm length, 13 mm width and 3 mm thickness. The specimen was fixed on pneumatic holders and load was applied hydraulically till rupture occurs. The values of tensile strength and percentage of elongation were obtained from the Stress-Strain Curve on the screen.



Figure 4 Test sample undergoing tensile test

#### 2.4.2 Hardness Test

Shore hardness is a measurement to determine the resistance of material to indentation by indenter. The higher the hardness number, the greater the resistance properties. Hardness test was performed by using

Digital Shore Scale D type Durometer according to ASTM D2240. The sample of the composite was placed on a flat surface and the indenter was pressed against the sample. The hardness of the samples was measured by the depth of the indentation and the reading was registered on the dial indicator, the reading was taken immediately after establishment of firm contact. The hardness characteristic tends to change at the edges of the sample, so this measurement should be taken at least 12 mm from the edge.

#### 2.4.3 Density Measurement

Density measurement was done to determine the specific densities of the prepared composites by using Electronic Densimeter. The density of the sample was measured by weighing the sample first, then immersing it in distilled water immediately. The density value of the sample was taken when the reading reached the equilibrium value.

#### 2.4.4 Microstructure Analysis

The interfacial bonding between the PLF and PP were examined under Inverted Microscope. Samples were cold mounting in a PVC pipe by using polymerizing resin (resin Mecaprex KM-U). This mounting were done to facilitate handling during microstructure analysis process. This process is done to ensure that the samples are in firm and flat condition.

### 3.0 RESULTS AND DISCUSSION

The effect of fiber loading on the random oriented composites is shown in Figure 5, Table 3 and Figure 6. It was observed that the tensile stress of the composite has increased with the increment of PLF loading by 12.9% at 30 wt.% PLF loading and dropped drastically by -76.4% with the addition of 70% PLF loading. This is may be due to at high PLF loading, the fibers act as flaws and the adhesion between fibers and matrix were not perfectly bonded. Threepopnatkul *et al.* in 2009 [21] stated that, good adhesion between the fibers and matrix makes it feasible for stress transfer to take place from the matrix to the fibers, thereby

improving the strength of the composite. The addition of 50 and 60 wt.% PLF loading decreased the tensile stress by -68% and -60% respectively compared to the tensile stress of plain PP.

From Table 3, it can be noticed that at 70 wt.% of PLF loading has shown the lowest value of tensile stress and strain. The elasticity of PP has decreased with the increments of PLF, therefore the strain of the composite also has decreased and the composite becomes more brittle. This is possibly due to high fiber-to fiber interactions, which the PP as matrix was not perfectly firm with the PLF [12, 22].

Meanwhile Figure 6 shows the graph of hardness (Shore-D) and density ( $\text{g}/\text{cm}^3$ ) versus PLF loading (wt.%) in PLF/PP composites. The addition of 30 wt.% fiber decreased the hardness by -14.7% and also increased the density by 3.33% as compared to the hardness and density of plain PP. The increment of PLF loading up to 50 wt.% shown similar result with 30 wt.% PLF loading. Moreover, for PLF loading 60 wt.% up to 70 wt.%, of the hardness value is shown the lowest value. This is due to less wetted of PP with PLF.

The microstructure of each composite is shown in Table 4. Based on the microstructure analysis of each sample, it shows that the voids percentage was increased as PP content is decreased. The result also shows poor adhesion between the PLF and PP. The properties of the composites were dependable on the reinforcement, matrix and their interfacial bonding, in which the load acting on the matrix has to be transferred to the reinforcement via the interface [19 & 23].

The result of this study demonstrates that at 30 wt.% PLF loading shows a good adhesion between the PLF and PP, and this has held the PLF firmly. Accordingly, this has increased their mechanical properties as compared to 40 up to 70 wt.% PLF loading. Meanwhile at 60 wt.% up to 70wt.% PLF loading, it clearly shows the high void percentage due to less wetted of PP with the PLF. The voids between PLF and PP lead to poor adhesion and affected their mechanical properties. Thus, voids that has been formed was probably caused by incompletely wettability or bonding between PP and PLF during the fabrication process [23]. The composite material that has weak interfacial bonding can cause failure at the interface [12&24].

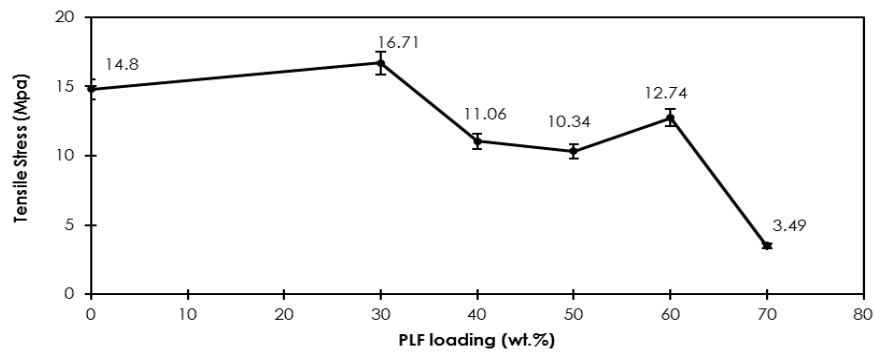


Figure 5 Tensile stress (MPa) versus PLF loading (wt.%)

Table 3 Tensile properties of the samples

No	PLF loading (wt.%)	Tensile stress, $\sigma$ (MPa)	Modulus Young, E (MPa)	Strain, $\epsilon$ (%)
1	0	14.8 $\pm$ 0.05	1700 $\pm$ 0.05	9.00 $\pm$ 0.05
2	30	16.71 $\pm$ 0.05	360 $\pm$ 0.05	4.59 $\pm$ 0.05
3	40	11.06 $\pm$ 0.05	640 $\pm$ 0.05	1.72 $\pm$ 0.05
4	50	10.34 $\pm$ 0.05	510 $\pm$ 0.05	2.01 $\pm$ 0.05
5	60	12.74 $\pm$ 0.05	280 $\pm$ 0.05	4.49 $\pm$ 0.05
6	70	3.49 $\pm$ 0.05	370 $\pm$ 0.05	0.95 $\pm$ 0.05

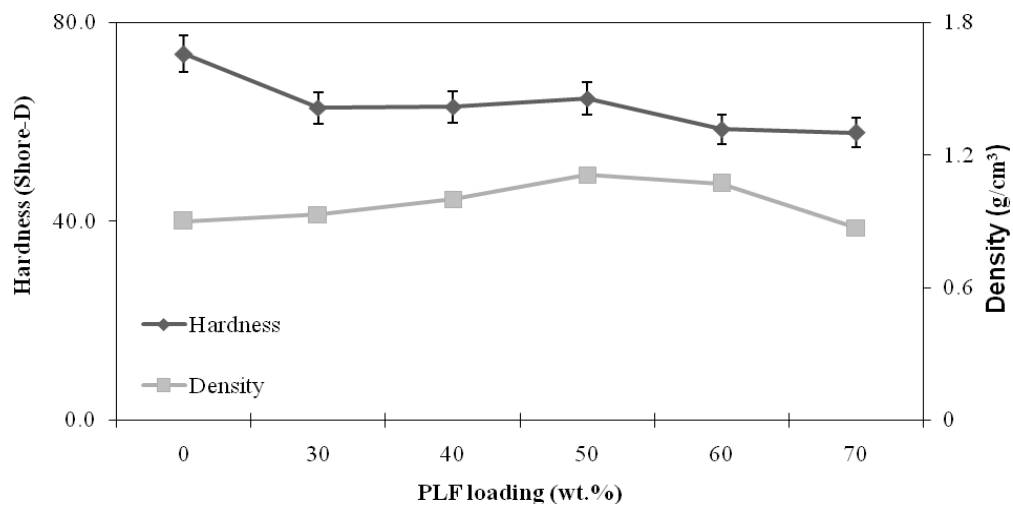


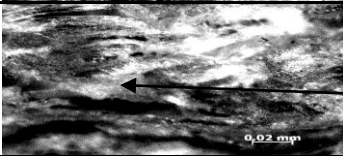
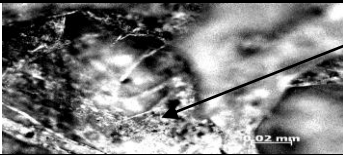
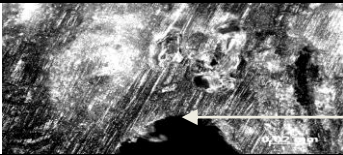
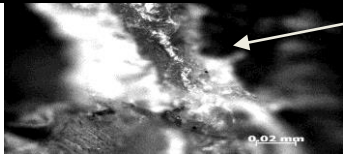


Figure 6 Hardness (Shore-D) and Density (g/cm<sup>3</sup>) versus PLF loading (wt.%)

**Table 4** Tensile properties of the samples

Ratio PLF/PP (wt.%)	Microstructure view
0/100	
30/70	
40/60	
50/50	
60/40	
70/30	

#### 4.0 CONCLUSION

The effects of pineapple leaf fiber loading with the random oriented on the properties of PLF/PP composite have been studied and analysed. The results of the present study show that the PLF loading accept 30 wt% PLF, have decreased the mechanical properties of PLF/PP composite compared to pure PP. The lower value of tensile stress and hardness may be attributed to voids, fiber-to-fiber interaction and poor preparation during extracting the fiber and dispersion problem. Based on the addition of PLF loading, it can be concluded that the addition of 30 wt.% PLF loading is the best mechanical properties comparable to others composition ratios (40, 50, 60 and 70 wt.%), which are 16.71 MPa, 62.83 Shore-D and 0.93 g/cm<sup>3</sup> respectively. It also found that the void percentage and interfacial bonding between the PLF and PP has affected the mechanical properties of the PLF/PP composite. However, the aim in this study is to explore the potential of PLF/PP composites. Improvement of the adhesion between PLF and PP, PLF extraction process, distribution and

orientation of the fiber will be the focus in our future work.

#### Acknowledgement

The authors would like to thank the Malaysia Ministry of Higher Education, Malaysia Ministry of Science, Technology and Innovation for sponsoring this work under the short term grant PJP/2013/FKM (14A) /S01240. Our gratitude also goes to the Advanced Material Research Group (A-MAT), Faculty Mechanical Engineering, University Teknikal Malaysia Melaka (UTeM) for providing the facilities and support during this research.

#### References

- [1] Dhal, J. P. & Mishra, S. C. 2013. Processing and Properties of Natural Fiber-Reinforced Polymer Composite. *Journal of Materials*. 1-6.
- [2] Selamat, M. Z., Kasim, A. N., Shamsudin, S. A., Mohd Daud, M. A. & Dhar, S. 2014. Effect Of Bamboo Fibre Length On The Mechanical Properties Of Bamboo

- Fibre/Polypropylene Composite. 8th MUCET. Melaka, Malaysia.
- [3] Chandramohan, D. & Marimuthu. K. 2011. Tensile and Hardness Tests on Natural Fiber Reinforced Polymer Composite Material. *International Journal of Advanced Engineering Sciences and Technologies*. 6: 097-104.
- [4] Phong, N. T., Fujii, T., Chuong, B. & Okubo, K. 2012. Study on How to Effectively Extract BFs from Raw Bamboo and Waste water Treatment. *Materials Science Research*. 1: 144-155.
- [5] Vinod, B. & Sudev, L. J. 2013. Effect of Fiber Orientation on the Flexural Properties of PLAF Reinforced Bisphenol composites. *International Journal of Science and Engineering Applications*. 2: ISSN-2319-7560.
- [6] Abdul Khalil, H. P. S., Bhat, I.U.H., Jawaid, M., Zaidon, D.Hermawan, A., Hadi. Y.S. 2012. Bamboo Fiber Reinforced Biocomposites: A review. *Materials and Design*. 42: 353-368.
- [7] Raghavendra, G., Acharya, S. K., Deo, P., & Mishra, P. 2012. Fabrication-modelling and analysis on tribological performance of natural composites using taguchi approach. *Procedia Engineering, International Conference on Modelling Optimization and Computing*. 38: 2635-2644
- [8] Jeyanthi, S. & Janci Rani, J. 2012. Influence of natural long fiber in mechanical, thermal and recycling properties of thermoplastic composites in automotive components. *International Journal of Physical Sciences*. 7: 5765-5771.
- [9] Kongkeaw, P., Nhuapeng, W. & Thamajaree, W. 2011. *The Effect of Fiber Length on Tensile Properties of Epoxy Resin Composites Reinforced by the Fibers of Bamboo*. 2001: 46-48.
- [10] Mohamed, A. R., Sapuan, S. M., Shahjahan, M. & Khalina, A. 2009. Characterization of pineapple leaf fibers from selected Malaysian cultivars. *Journal of Food, Agriculture & Environment*. 7: 235- 240.
- [11] Shyamraj, R., Sivasubramanian, P. & Dhanusha, P. B. 2013. Investigations on Mechanical Properties of Pineapple Fiber Reinforced Polymer Composite Material. *International Journal of Scientific & Engineering Research*. 4: 4-8.
- [12] Arib, R. M. N., Sapuan, S. M., Ahmad, M. M. H. M., Paridah, M. T. & Khairul Zaman, H. M. D. 2004. Mechanical properties of pineapple leaf fiber reinforced polypropylene composite. *Materials and Design*. 27: 391-396.
- [13] Fairuz, I. R., Ahmad Nizam, A., Azmin Shakrine, M. R., Dayang Laila, A. A. M. 2012. Factorial study on the tensile strength of a coir fiber-reinforced epoxy composite. *AASRI Procedia*. 3: 242-247
- [14] Mwaikabo, L. & Ansell, M. 2002. Chemical modification of hemp, sisal, jute and kapok fibers by alkalization. *J. App. Polym. Sci*. 84: 2222-2234
- [15] Hussain, S. A., Pandurangadu, V. & Palanikuamr, k. mechanical properties of green coconut fiber reinforced HDPE polymer composite. *International Journal Of Engineering Sciece And Technology*. 3: 7942-7952
- [16] Zakaria, S., Hamzah, H., Murshidi, J. A., Deraman, M. 2001. Chemical modification on lingo cellulosic polymeric oil palm empty fruit bunch for advanced material. *Advance in Polymer Tech*. 20(4): 289-295
- [17] Sain, M. M., Kokta, B. V. 1994. Polyolefine-wood filler composite. I. performance of m-phenylene bismaleimide-modified wood fiber in polypropylene composite. *J. App. Polym. Sci*. 54: 1545-1559
- [18] Yang, H. S., Kim, H. J., Lee, B. J., Hwang, T. S. 2007. Effect of compatibilizing agent on rice husk flour reinforced polypropylene composites. *Compos. Struct*. 77: 45-55
- [19] Siregar, J. P., Sapuan, S. M., Rahman, M. Z. A. & Zaman, H. M. D. K. 2012. Effects of alkaline treatments on the tensile properties of pineapple leaf fiber reinforced high impact polystyrene composites. *Pertanika Journal Science & Technology*. 20: 409-414.
- [20] Mohamed, A. R., Sapuan, S. M. & Khalina, A. 2010. Selected properties of hand-laid and compression molded vinyl ester and pineapple leaf fiber (PALF) - reinforced vinyl ester composites. *International Journal of Mechanical and Materials Engineering IJMME*. 5: 68-73.
- [21] Threepopnatkul, P., Kaerkitcha, N. & Athipongarporn, N. 2009. Effect of surface treatment on performance of pineapple leaf fiber-polycarbonate composites. *Elsivier Journal, composite part B: Engineerin*. 40: 628-632.
- [22] George, J., Bhagawan, S. S., Prabhakaran, N. S. & Thomas, S. 1995. Short pineapple-leaf-fiber-reinforced low-density polyethylene composites. *Journal of Applied Polymer Science*. 57: 843-854.
- [23] Kongkeaw, P., Nhuapeng, W. & Thamajaree, W. 2011. *The Effect of Fiber Length on Tensile Properties of Epoxy Resin Composites Reinforced by the Fibers of Bamboo*. 2001: 46-48.
- [24] Luo, S. & Netravali, N. 1999. Mechanical and thermal properties of environment-friendly "green" composites made from pineapple leaf fibres and poly (hydroxybutyrate-co-valerate) resin. *Polym Compos*. 20: 367-78.