IOP Conf. Series: Materials Science and Engineering **438** (2018) 012026 doi:10.1088/1757-899X/438/1/012026

Mechanical, Thermal and Morphological Properties of Pineapple and Betel Nut Husk Fiber Reinforced Hybrid Polypropylene Composites

M. Akter, E. Jahan and M. Hasan

Department of Materials and Metallurgical Engineering, Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

Abstract: Hybrid composites have extensive engineering application where strength to weight ratio, low cost and ease of fabrication are required. In recent times hybrid composites have been established as highly efficient, high performance structural materials. Structures made of composites have a long life and need little maintenance. Present research presents a review of the current status of hybrid composite materials technology in terms of mechanical, thermal and morphological properties. Hybrid composites were manufactured with pineapple and betel nut husk as hybrid fibers and polypropylene as matrix using a hot press machine. Fiber loading was varied at 5, 10 and 15 wt%, while pineapple and betel nut husk fiber ratio was set at 1:1. For mechanical characterization, tensile, flexural and hardness tests were conducted with the composites. Thermal properties were measured using thermo gravimetric analysis. To observe surface morphology of the samples, scanning electron microscope was used. Tensile test of the composites showed a decreasing trend of tensile strength with increasing fiber content. Tensile modulus initially increased with fibers loading, then decreased at 10% fiber content. Flexural strength and flexural modulus were found higher for 10% fiber loaded composite as compared composites containing 5% and 15% fiber. From the TGA analysis, it is observed that 10% fiber loaded composites had highest thermal stability among all manufactured composites. According to scanning electron microscopy, 10% fiber loaded composite showed more adhesion as compared to 5% and 15% fiber loaded composites. Fiber agglomeration was also observed in 15% fiber loaded composite.

Keywords: Hybrid Composite; Mechanical Properties; Thermal Properties; Morphology

1. Introduction

Hybrid composites contain more than one type of fiber in a single matrix material. In principle, several different fiber types may be incorporated into a hybrid, but it is more likely that a combination of only two types of fibers would be most beneficial. They have been developed as a logical sequel to conventional composites containing one fiber. Hybrid composites have unique features that can be used to meet various design requirements in a more economical way than conventional composites. This is because expensive fibers like graphite and boron can be partially replaced by less expensive fibers such as glass and Kevlar. Some of the specific advantages of hybrid composites over conventional composites

include balanced strength and stiffness, balanced bending and membrane mechanical properties, balanced thermal distortion stability, reduced weight and/or cost, improved fatigue resistance, reduced notch sensitivity, improved fracture toughness and/or crack arresting properties, and improved impact resistance [1].

Natural fibers are now dominate the automotive, construction and sporting industries by its superior mechanical properties. These natural fibers include flax, hemp, jute, sisal, kenaf, coir and many others. Various advantages of natural fibers are low density, low cost, low energy inputs and comparable mechanical properties and also better elasticity of polymer composites reinforced with natural fibers, especially when modified with crushed fibers, embroidered and 3-D weaved fibers. Experimental techniques can be employed to understand the effects of various fibers, their volume fractions and matrix properties in hybrid composites. These experiments require fabrication of various composites with the above mentioned parameters, which are time consuming and cost prohibitive [2].

One of the major scientific challenges for the composite engineers is the development of new stronger and tougher lightweight structural materials supporting latest technologies and design concepts for the complex shaped structures like aircraft, automotive structures, and large wind turbine blade structures. The development of composite materials improving their performance limits based on the reinforcement of two or more fibers (synthetic fiber with another synthetic fiber or synthetic fiber with natural fiber or synthetic fiber with metallic fibers) in a single polymeric matrix, which leads to the advanced material system called hybrid composites with a great diversity of material properties, is still in its infancy. This is a major challenge that can only be met through an understanding of the relationships between materials architecture and mechanical response, as well observing microstructure formation [3]. Pineapple fiber and betel nut fiber were used in present research. These fibers are available and very cheap n context to the economic condition of Bangladesh. The objective of the research was to develop hybrid composite by using two natural fibers, which are abundant, inexpensive and green in nature. The purpose was to characterize pineapple and betel nut fibers reinforced PP hybrid composite by finding out their mechanical, thermal and morphological characteristics.

2. Materials and Methods

2.1 Materials

Pineapple fibers were collected from the pineapple leaf. The leaves were smashed and then the fibers were collected. Betel nut fibers were collected from the upper portion of the betel nut. Then they were cleaned and dried. Polypropylene is a very common thermoplastic, which is very available in the local market. Commercial grade Polypropylene was thus collected from local market.

2.2 Composite Preparation

Discontinuous fiber composites were prepared in present research. Hybrid composites of polypropylene matrix were prepared by varying fiber content at 5%, 10% and 15 wt%, while of betel nut and pineapple fibers were used at 1:1. Hot press technique was utilized for composite preparation. At first fibers were weighted according to required fraction needed. Then both fibers were cut into 3-5 mm size in length. Then to allow the removal of moistures, fibers were dried in an oven at 80°C for 20 minutes before preparing each composite. The required amount of polyproylene was weighed. To prevent voids, water bubbles, poor fiber matrix adhesion the polypropylene was dried in an oven at 80°C for 20 minutes before preparing each composite. Both fibers were mixed in a container [4]. Mold surface was rubbed with emery paper and cleaned very carefully. Mold releasing agent was sprayed on the mold surface. Then polypropylene was distributed on the female mold, then fibers were given as layer on the polypropylene. Remaining part of polypropylene was distributed as the upper layer. Then the mold was closed by male mold. The mold was placed in the hot pressing machine. The capacity of the machine is maximum load 30kN maximum operating temperature 300°C. The mixtures of fiber and matrix were allowed to press at 30kN pressure and the temperature was initially raised to 160°C. When the temperature was reached at 160°C then sample was put in that temperature at 15-20 minutes, after that the temperature was raised to 190°C. When the temperature was reached at 190°C, then water was supplied to cool the mold to room

temperature. After cooling the mold or die the pressure was released and the specimen was carefully withdrawn from the die [5].

2.3 Mechanical Tests

Tensile tests were conducted according to ASTM D 638-01using an Instron machine. Each test was continued until the samples become failed. By this test, tensile properties of the composites were determined. The three point bend test is generally performed on composite material. Specimens were prepared according to ASTM D 790-00 using the same Instron machine. Size was specified by using a grinding machine. The hardness of polymer composite is most commonly measured by the Shore (Durometer) test. This method measures the resistance of composites toward indentation and provides an empirical hardness value that does not necessarily correlate well to other properties or fundamental characteristics. In present research shore D hardness scale was used.

2.4 Scanning Electron Microscopy (SEM)

Surface morphology of the composites of varying fiber percentage was observed by using a scanning electron microscope. The surface of the fiber was made conductive by giving platinum coating using a sputtering machine. The fiber was then observed in vacuum condition into the SEM machine.

2.5 Fourier Transform Infrared Spectroscopy (FTIR)

Powder sample was made to perform FTIR, Potassium bromide (KBr) was taken as a reagent which was mixed with the sample (KBr: sample = 100:1). The mixture was taken into a dice. Then it was pressed by a hand pressing machine. The infrared spectra of composites were recorded on a Nicolet 380 spectrophotometer with co-addition of 32 scans.

2.6 Thermogravimetric Analysis (TGA)

TGA measures the amount of weight change of a material, either as a function of increasing temperature, or isothermally as a function of time, in an atmosphere of nitrogen, helium, air, other gas, or in vacuum. Inorganic materials, metals, polymers and plastics, ceramics, glasses and composite materials can be analyzed. Temperature ranges from 25°C to 900°C routinely. The maximum temperature was set at 500°C during present research.

3. Result and Discussion

3.1 Mechanical Properties

3.1.1 Tensile Test Results. Figure 1 shows the effect of fiber loading on tensile strength of the composites. The tensile strength decreased with an increase in fiber loading (Figure 1 (a)). As the fiber loading increased, the interfacial area between the fiber and the matrix increased, which was weak because of worsening interfacial bonding between the cellulose based hydrophilic filler (PAL and BNH) and hydrophobic matrix PP [6, 7]. This consequently decreased the tensile strength. It is observed that the Young's modulus increased with an increase in fiber loading then again decreased with an increase in fiber loading (Figure 1 (b)). This is because with an increase in fiber content, the brittleness of the composite increased and stress-strain curves became steeper. Poor interfacial bonding creates partially separated micro spaces which obstruct stress propagation between the fiber and the matrix. As the fiber loading increases, the degree of obstruction increases, which in turn increased the stiffness [8]. The elongation at break reduced with an increase of fiber weight percentage due to the low percentage of elongation at break of the fibers compared to PP (Figure 1 (c)).

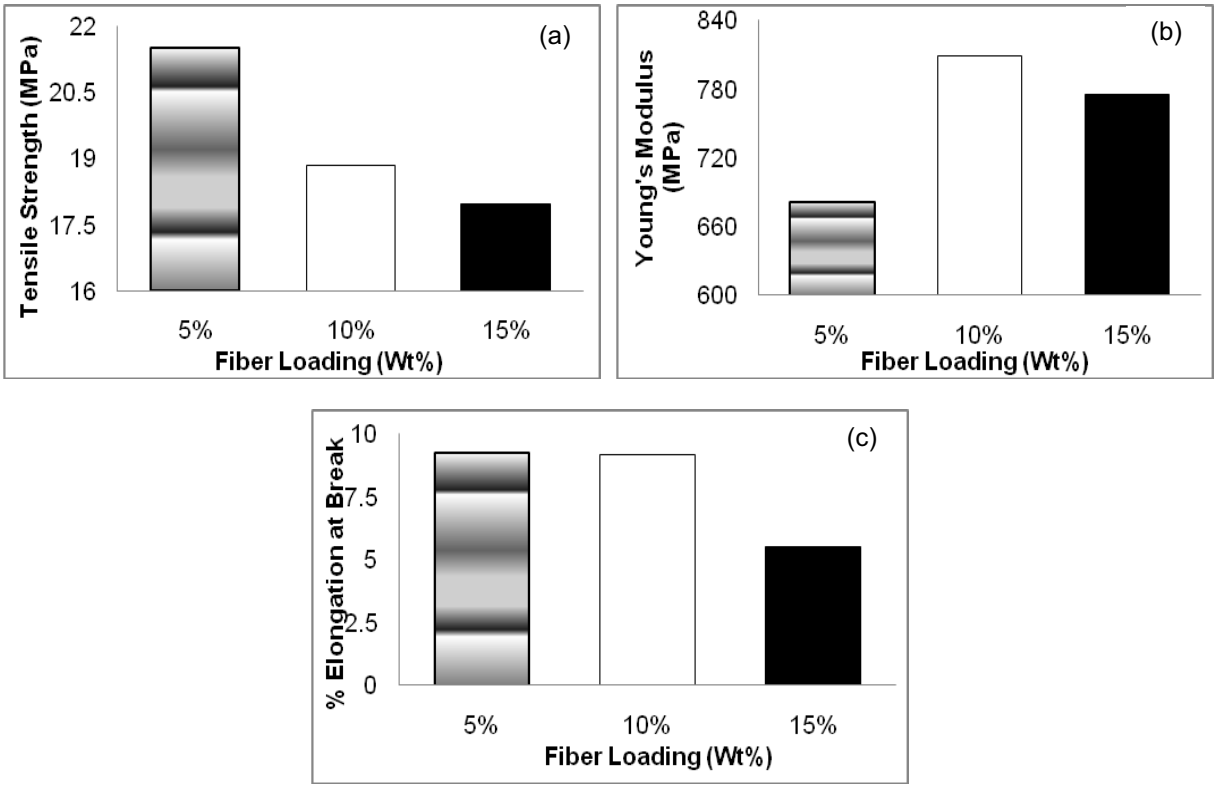

Figure 1. Variation of (a) tensile strength, (b) Young's modulus and (c) % elongation at break against fiber loading.

3.1.2 Flexural Test Results. Flexural properties of the composite samples were measured for each fiber content (5, 10, 15 weight %) with the help of stress-strain curves and respective equation. The flexural strength and flexural modulus of raw pineapple leaf fiber and betel nut husk fiber (PAL: BNH=1:1) reinforced hybrid polypropylene composites at different fiber loadings are shown in Figures 2 (a) and 2 (b) respectively. The flexural strength increased with an increase in fiber loading. This may be due to the favorable entanglement of the polymer chain with the filler, which has overcome the weak filler matrix adhesion with increasing filler content. The flexural modulus values of the composites for different fiber loadings are shown in Figure 2 (b). It is observed that the flexural modulus increased with an increase in fiber loading, then again decreased with an increase in fiber loading.

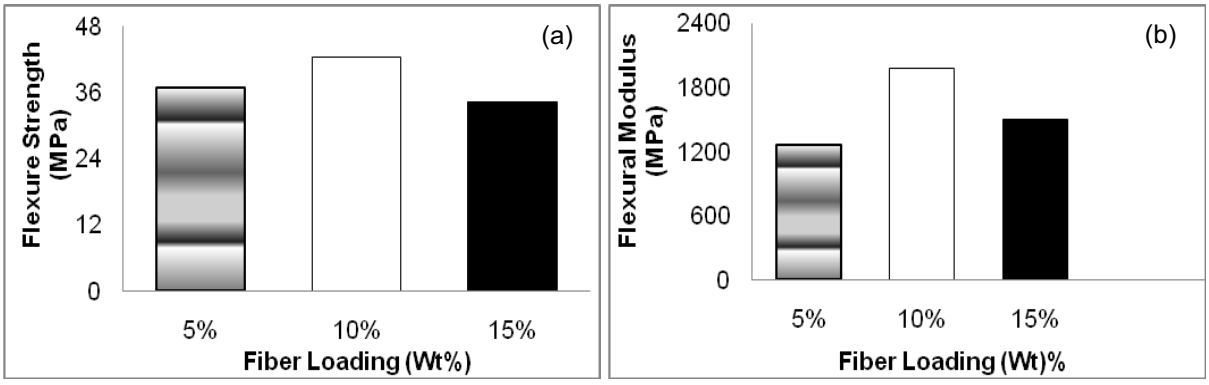

Figure 2. Variation of (a) flexural strength and (b) flexural modulus against fiber loading.

3.1.3 Hardness Test Results. Hardness of a composite depends on the distribution of the filler into the matrix. Usually the more flexible matrix causes the resultant composites to exhibit lower hardness. As shown in Figure 3, incorporation of fiber into the PP matrix has reduced the flexibility of the matrix resulting in more rigid composites. Due to the increase of stiffness of respective composite the hardness of the composites showed increasing trend with an increase in the fiber content [9, 10]. Better dispersion of the filler into the matrix with minimization of voids between the matrix and the filler also enhanced hardness [11].

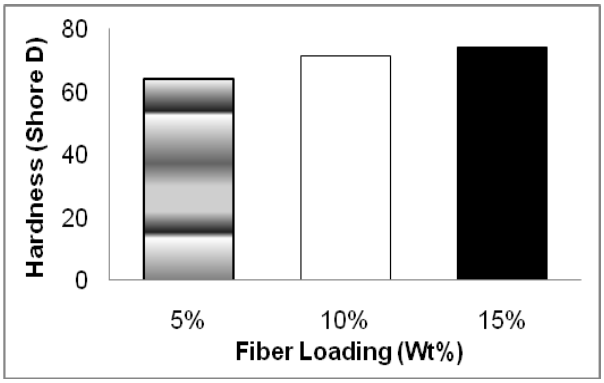

Figure 3. Variation of hardness against fiber loading.

3.2 Morphological Properties

In order to study surface morphology and interfacial adhesion between the hybrid fiber and PP of manufactured composites, SEM images were taken for different fiber loaded composites. SEM micrographs of composites with 5, 10 and 15 wt% fiber reinforced composites are shown in Figure 4. Fiber pull-out was observed in case of 5% and 15% fiber loaded composites (Figures 4 (a) and 4 (c) respectively). 15% fiber loaded composite also had fiber agglomeration. On the other hand, very good wetting between fiber and matrix is also observed in the 10% fiber loaded composite (Figure 4 (b)) [12]. Thus 10% fiber loaded composite showed more adhesion as compared to 5% and 15% fiber loaded composites.

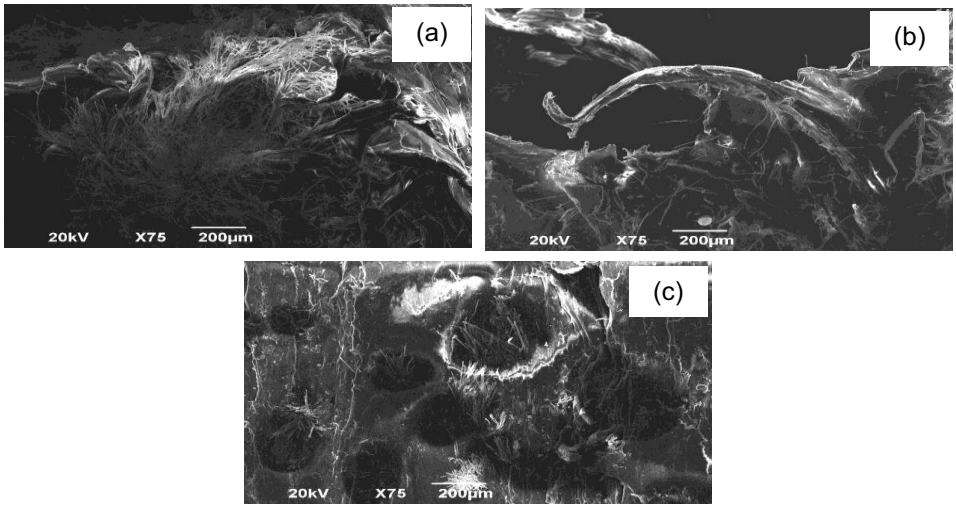

Figure 4. SEM micrographs of (a) 5, (b) 10 and (c) 15 wt% fiber loaded PP composites.

3.3 FTIR Analysis Results

FTIR curves of 5, 10 and 15 wt% betel nut husk fiber and pineapple fiber reinforced composites are shown in Figure 5. According to the results there are no significant differences between the peaks in different loading fiber composites of FTIR spectra. The only noticeable thing is that the FTIR peaks of 15% loaded fibers are wider than others. It is observed that the absorption peak around 1740 cm-1, corresponding to the C=O stretching of hemi-cellulose in the raw fibers composites. Moreover, absorption peak of lignin is found corresponding to Syringyl (S) ring breathing with C-O stretching around 1372 cm-1, C=O stretching in 2838.7 cm-1. C-H stretching in aromatic methoxyl groups and aliphatic methyl and methylene groups of the side chains and the band at 2930 cm-1 is due to the C-H stretching of aromatic methoxyl groups and methyl and methylene groups of the side chains. The absorption peak at 3420 cm-1 is attributed to the hydroxyl stretching vibrations, aromatic C-H in-plane deformation (typical of S units) plus secondary alcohols plus C=O stretching around 1261 cm-1, C=C stretching of the aromatic ring of the guaiacyl unit at 1630 cm-1. The absorption peak at the range of 2900-2880 cm-1 is due to C-H vibration of CH_2 group of PP [13].

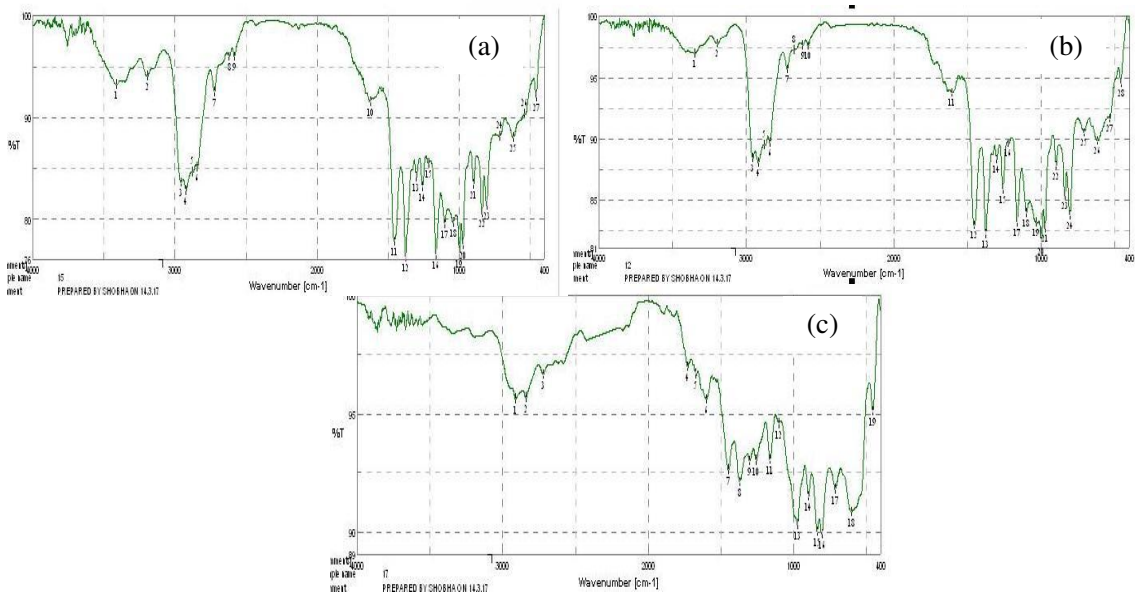

Figure 5. FTIR curves of (a) 5, (b) 10 and (c) 15 wt% fiber loaded PP composites.

3.4 TGA Results

For the manufacturing of composites, the thermal stability of the fiber is very important. TGA curves of composites with 5, 10 and 15 wt% fiber loading are shown in Figure 6. In TGA curve of 5% fiber (PAL: BNH=1: 1) reinforced composite, moisture loss occurred at <100 ^{O}C. Thermal degradation occurred at around 225 to 358 ^{O}C. In 10% fiber (PAL: BNH=1: 1) reinforced composite, moisture loss occurred at <100 ^{O}C. Thermal degradation occurs at around 250 to 410 ^{O}C. In 15% fiber (PAL: BNH=1: 1) reinforced composite moisture loss occurred at <100 ^{O}C. Thermal degradation occurred at around 223 to 374 ^{O}C. Thus 10% fiber loaded composite had highest thermal stability among all prepared composites. This was due to better adhesion between fibers and matrix in case of 10% fiber loaded composite [14, 15].

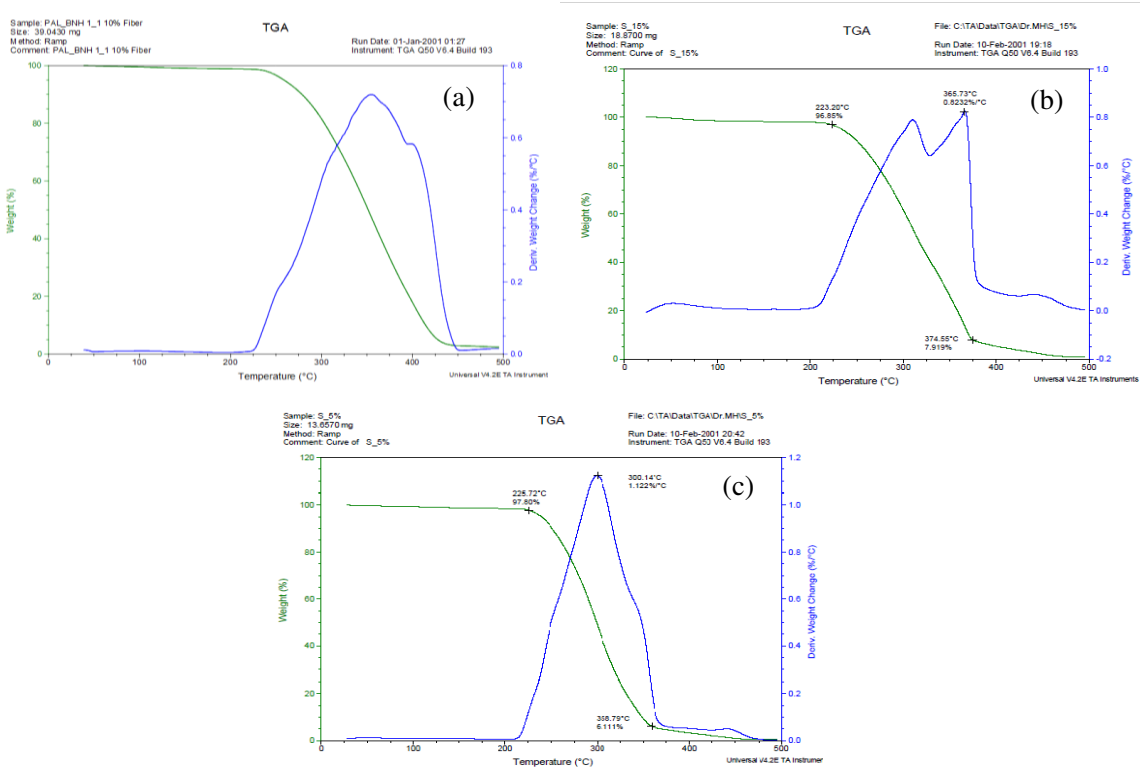

Figure 6. TGA curves of (a) 5, (b) 10 and (c) 15 wt% fiber loaded PP composites.

4. Conclusion

The objective of present research is to show improved physico-mechanical and thermal properties in hybrid polymer composite. Pineapple and betel nut fiber were used, which are cheap and available. The tensile strength of prepared composites decreased, while the Young's modulus, flexural strength and flexural modulus increased with increase in fiber loading. SEM images indicated that 10 wt% fiber loaded composite showed more adhesion as compared to 5 and 15 wt% fiber loaded composites. Very good wetting between fiber and matrix was also observed in the 10 wt% fiber loaded composite. FTIR spectroscopic analysis identified chemical bonds in a molecule by producing an infrared absorption spectrum for 5, 10 and 15 wt% fiber loaded composites. The spectra produce a profile of the sample, a distinctive molecular fingerprint that can be used to screen and scan samples for different components. According to TGA results, 10% fiber loaded composites had highest thermal stability among all manufactured composites.

5. References

[1] Jyoti P D and Mishra S C 2013, *Processing and properties of natural fiber-reinforced polymer composite*, Journal of Materials, Vol. 2013, pp. 1-6.

[2] Lai W L and Mariattim M 2008 *The Properties of woven betel palm (Areca catechu) reinforced polyester composites*, Journal of Reinforced Plastic and Composites, Vol. 27(9), pp. 925-935.

[3] Kuruvilla J 2007 *Natural fiber reinforced polymer composites*: *status and future*, Proc. *ICPP*-2007, pp. 316-327.

[4] Srinivasulu N V and Tejaswi V 2012 *Mechanical properties of polymer composite materials*, International Journal of Research in Engineering and Technology, Vol. 1, pp. 78-81.

[5] Asim M, Abdan K, Jawaid M, Nasir M, Dashtizadeh Z, Ishak M R and Hoque M E 2015 *A review on pineapple leaves fibre and its composites*, International Journal of Polymer Science, Vol. 2015, Article ID 950567.
[6] Yusriah L, Sapuan S M, Zainudin E S and Mariatti M 2012 *Exploring the potential of betel nut husk fiber as reinforcement in polymer composites: Effect of fiber maturity*, Procedia Chemistry**,** Vol. 4, pp. 87-94.
[7] Rahman M R, Haque M M, Islam M N and Hasan M 2009 *Mechanical properties of polypropylene composites reinforced with chemically treated abaca*, Composites A, Vol. 40, pp. 511-517.
[8] Prabhakaran R D, Andersen T L, Markussen C M, Madsen B and Lilholt H 2013 *Tensile and compression properties of hybrid composites–a comparative study,* Proc. of the International Conference on Composite Materials, Denmark, pp. 1029-1035.
[9] Haque M M, Islam M S, Islam M S, Islam M N, Huque M M and Hasan H 2010 *Physico-mechanical properties of chemically treated palm fiber reinforced polypropylene composites*, Journal of Reinforced Plastics and Composites Vol. 29, pp. 1734-1742.
[10] Haque M M, Rahman M R, Islam M N, Huque M M and Hasan H 2010 *Physico-mechanical properties of polypropylene composites reinforced with chemically treated coir and abaca fiber*, Journal of Reinforced Plastics and Composites Vol. 29, pp. 2253-2261.
[11] Ashik K P and Sharma R S 2015 *A review on mechanical properties of natural fiber reinforced hybrid polymer composites,* Journal of Minerals and Materials Characterization and Engineering, Vol. 3(5), pp. 420-426.
[12] Daud Z, Hatta M M Z, Kassi M A S and Aripi M A 2014. *Analysis of the chemical compositions and fiber morphology of pineapple (Ananascomosus) leaves in Malaysia*, Journal of Applied Sciences, Vol. 14, pp. 1355-1358.
[13] Siddika S, Monsura F, Hasan M and Hassan A *2014 Effect of reinforcement and chemical treatment of fiber on the properties of jute-coir fiber reinforced hybrid polypropylene composites,* Fibers and Polymers, Vol. 15(5), pp. 1023-1028.
[14] Bucci D Z, Alberti L D, Souza D F and Barcellos I O 2014 *Studies on mechanical and thermal properties of PHB biocomposites with rice hull ash*, Materials Science Forum, Vol. 775-776, pp. 557-561.
[15] Jamil Md S, Ahmed I and Abdullah I 2006 *Effect of rice husk filler on the mechanical and thermal properties of liquid natural rubber compatibilized high-density polyethylene natural rubber blends,* Journal of Polymer Research, Vol.13, pp.315-321.

Acknowledgment
The authors are thankful to the department of Materials and Metallurgical Engineering, Bangladesh University of Engineering and Technology for their technical and financial support during the work.