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Physico-Mechanical Properties of Pineapple Leaf and Banana Fiber Reinforced Hybrid Polypropylene Composites: Effect of Fiber Ratio and Sodium Hydroxide Treatment

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Abstract. Natural fibers are becoming abundant and viable substitute for the synthetic fibers day by day, as synthetic fibers are expensive and nonrenewable. The main aim of present research is to evaluate the effect of sodium hydroxide treatment and banana and pineapple leaf fiber ratio on mechanical and physical properties of pineapple leaf-banana fiber reinforced hybrid polypropylene composites. Hybrid composites were prepared using a hot press machine. Raw pineapple leaf and banana fiber were chemically treated with 5% sodium hydroxide to increase adhesion between the fibers and polypropylene. Both raw and alkali treated fibers at 5 wt% were utilized during composite preparation. Pineapple leaf and banana fiber ratios were varied in 1:1, 3:1 and 1:3. Morphological analysis (scanning electron microscopy) and mechanical (tensile, flexural and hardness) tests of prepared composites were subsequently conducted. Better adhesion between the fibers and polypropylene was observed in case of treated fiber composites as compared to raw fiber composites. Scanning electron microscopic analysis also showed better bonding between the fibers and polypropylene when pineapple leaf and banana fiber ratio was 3:1. Subsequently thebest set of mechanical properties was attained for that particular fiber ratio.

Keywords: Banana and pineapple leaf fiber; Polypropylene; Hybrid composite; Sodium hydroxide treatment.

1. Introduction

Natural fibers are ecofriendly, lightweight, strong, renewable, cheap and biodegradable. Natural fiber polymer consists a polymer matrix reinforced with high strength natural fiber. Natural fiber composites are attractive to industry because of their low density, low cost and ecological advantages over synthetic composites.Natural fiber containing composites are using in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc. Although synthetic fiber shows higher properties than natural fibers, all of these properties of natural fiber make natural fiber more attractive [1]. Hybrid

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composite can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases. Hybrid composites have received considerableattention in the scientific community recently. By using hybrid composites better properties can be achieved than binary systems containing one type of fiber dispersed in a matrix. So, hybrid composites can give a balanced pursuit of stiffness, strength and ductility, as well as bending and membrane related mechanical properties with weight savings, reduced notch sensitivity, improved fracture toughness,longer fatigue life and excellent impact resistance.The physical properties of natural fiberreinforced composites largely depend on the type of matrix, fiber weight, fiber ratio, bonding between fiber and matrix [2]. However, the main disadvantages of natural fibers in composites are the poor compatibility between fiber and matrix and the relatively high moisture sorption. Therefore, chemical treatments are considered in modifying the fiber surface properties [3]. Banana and pineapple leaf fibers, both are available and low cost natural fiber. Both fibers are bio degradable and light weight. Pineapple fruits are very important, but leavewaste materials of fruit which is producing natural fibers. Banana and pineapple leaf fiber both are lignocellulosic material. Cellulose and lignin content of banana fiber are 44-54% and 11-22% respectively [4]. On the other hand, pineapple leaf fiber has a cellulose content of 67-85% and lignin content of 4.4-15% [5]. Thus the pineapple leaf fiber is more strong fiber than banana fiber [6]. The aim of this research is to develop a new hybrid using inexpensive and eco-friendly banana and pineapple leaf fiber. Effects of fiber ratio and chemical treatment on physico-mechanical properties of pineapple leaf and banana fiber reinforced hybrid polypropylene composite were observed.

2. Materials and Methods

2.1 Materials

The thermoplastic polymer polypropylene (PP), supplied by the local marketin the form of homopolymer pellets, was used as matrix material. The PP was white in color.The melting point of the commercial PP lies in the range of 160-170°C, while the specific gravity is 0.90-0.91 [2]. Banana fiber was extracted from the pseudo stem sheath of the plant. Pineapple leaf fiber was collected from pineapple leaf, which is actually a left out portion of pineapple. When extracted, the fibers contained moisture. So, they were dried after extraction. The chemical used to both pineapple leaf and banana fiber is 5% NaOH.

2.2 Chemical treatment of natural fiber

Firstly 5% solution was prepared into a beaker. Then the dried extracted fibers were drowned into the solution and stirred properly, so that all fibers were wet with the solution. Then the beaker containing the solution with fiber was taken to the oven for heating. It was heated at 70ºC for about two and half hours. After two and half hours the beaker was taken out from the oven. Then the fibers were washed at first with tap water. Then they were washed with distilled water. The fibers contained water and evaporation was needed. That is why they were taken to the oven for the complete evaporation of moisture. They were heated for two hours in an oven at 180ºC. After complete evaporation of moisture they were taken out from the oven.

2.3 Manufacturing of composites

Hybrid composite of polypropylene and banana-pineapple leaf fiber was prepared using hot press machine. Hybrid composite was prepared for pineapple leaf and banana fiber in 3:1, 1:1 and 1:3 rations and 5wt% fibers. Composites were prepared by taking 5% NaOH treated pineapple and banana fiber at a ratio of 3:1 using the same hot press technique. Fibers were weighted according to the required volume fraction needed. Then both fibers were cut into 3 mm size in length. The required amount of polypropylene was weighted. To prevent voids, water bubbles and poor fiber matrix adhesion of the polypropylene was dried in an oven at about 80ºC for 20 minutes. Mold surface was cleaned very carefully and the mold releasing agent was sprayed over the mold surface properly for the easy removal of the product. Then at first a layer of polypropylene was poured into the female mould. Chopped fiber was given to the layer. Then again a layer of polypropylene was given on the chopped fiber. The female mould with randomly oriented fiber and polypropylene were covered with the male mould according to the indication provided in both mould. Then the die was placed in a hot pressing machine. In the present study, a hydraulic type machine having a capacity of maximum load of 50 kN and maximum temperature of 300ºC was used. The fiber matrix mixture was allowed to press at 30 kN pressures. The temperature was initially raised to 160ºC and hold there for around 20-25 minutes. After that the temperature was raised to 190ºC . The die was cooled to room temperature, pressure was released and the specimen was carefully withdrawn from the die. The same procedure was applied to other percentage of fiber. For making composite with treated fiber, the above procedure was followed.

2.4 Mechanical testing
Tensile, flexure and hardness tests of prepared composites were conducted. Tensile test was conducted according to ASTM D 638-01 using an Instron machine at a cross head speed of 5mm/min. Each test was continued until tensile failure. Static flexural tests were carried out according to ASTM D 790-00 using the same testing machine mentioned above at same crosshead speed. The hardness of composites was measured using a shore hardness testing machine on scale D.

2.5 Scanning Electron Microscopy Analysis
Surface morphology of the raw and chemically treated fiber composites were observed under a scanning electron microscope (Philips XL 30). The composites surface was initially made conductive by applying gold coating using a sputtering machine. The composites were then taken inside SEM, vacuum was created and micrographs were taken.

3. Results and Discussion

3.1 Effect of fiber ratio
3.1.1 Tensile properties. Tensile properties of composites were measured for pineapple leaf and banana fiber ratio of 3:1, 1:1 and 1:3 using stress strain curve. The variation of tensile strength, Young’s modulus and % elongation at break for the different pineapple leaf and banana fiber ratio are shown in Figure 1. Tensile strength of composites containing pineapple leaf and banana at 3:1 was higher as compared to composites containing those two fibers at 1:1 and 1:3 ratios (Figure 1 (a)). Banana fiber has low tensile strength as compared pineapple leaf fiber due to its low cellulose content. The cellulose content of pineapple leaf fiber is around 70-82% and the cellulose content of banana fiber is 48-50%The tensile strength of pineapple leaf fiber is 413-1627 MPa, while that ofbanana fiber is 198-780 MPa [4, 7]. Again Young's modulus of composites containing pineapple leaf and banana at 3:1 was higher as compared to composites containing those two fibers at 1:1 and 1:3 ratio (Figure 1 (b)). Young’s modulus of pineapple leaf fiber is 34.5-82.5 GPa and Young’s modulus of banana fiber is 6.6-25.6 GPa. So, higher concentration of pineapple fiber incorporation demands higher stress for the same deformation and results in the enhancement of Young’s modulus [1]. Finally composite containing 75% banana fiber had highest % elongation at break as comparedto other two composites pineapple fiber due to its lowest stiffness (Figure 1 (c)).

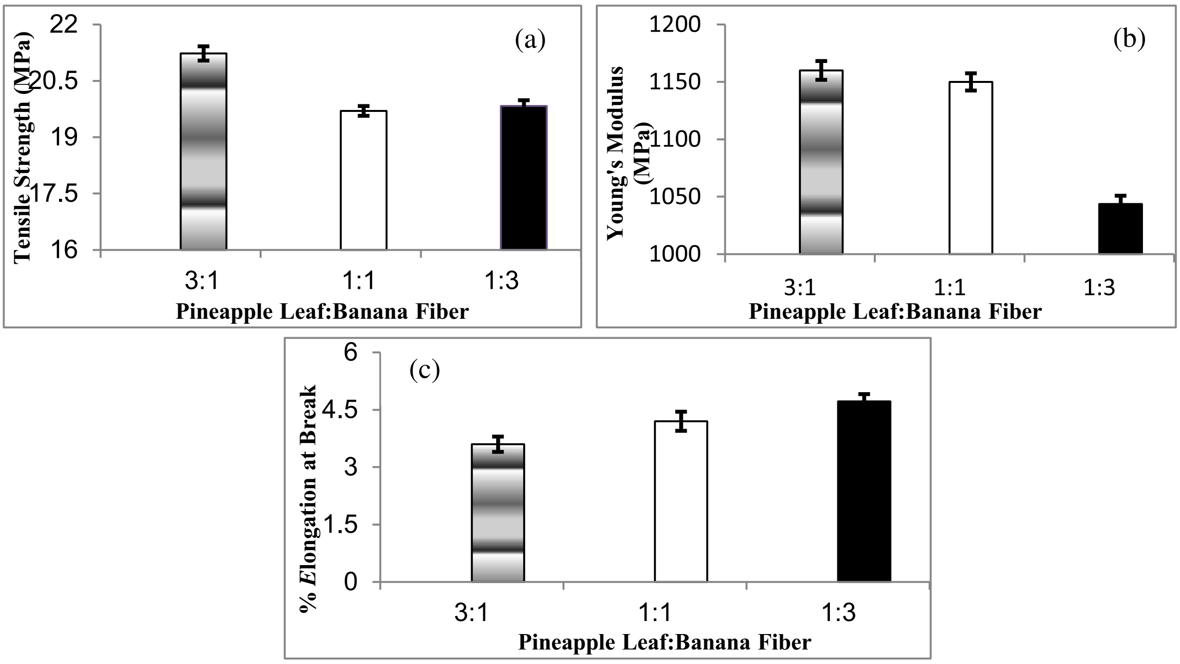

Figure 1. Variation of (a) tensile strength, (b) Young's modulus and (c) % elongation at break for different fiber ratio.

3.1.2 Flexural properties. Flexural properties of prepared composites were measured for pineapple leaf and banana fiber ratio of 3:1, 1:1, and 1:3 with the help of flexural stress/strain curves and respective equations. Flexural strength value of composites containing pineapple leaf and banana fiber at 3:1 ratio was higher as compared to compositecontaining pineapple leaf and banana fiber at 1:3 ratio (Figure 2 (a)). Thus with increase in pineapple fiber content,flexural strength increased. The same trend was also obtained for flexural modulus (Figure 2 (b)). Pineapple leaf fiber contains higher cellulose (70-82%) as compared to banana fiber (48-50%). It also contains lower amount of lignin (4.6-12%) as compared to banana fiber (19.17%). These may bethe reason of higher bending properties of composites containing higher pineapple leaf fiber [7, 8].

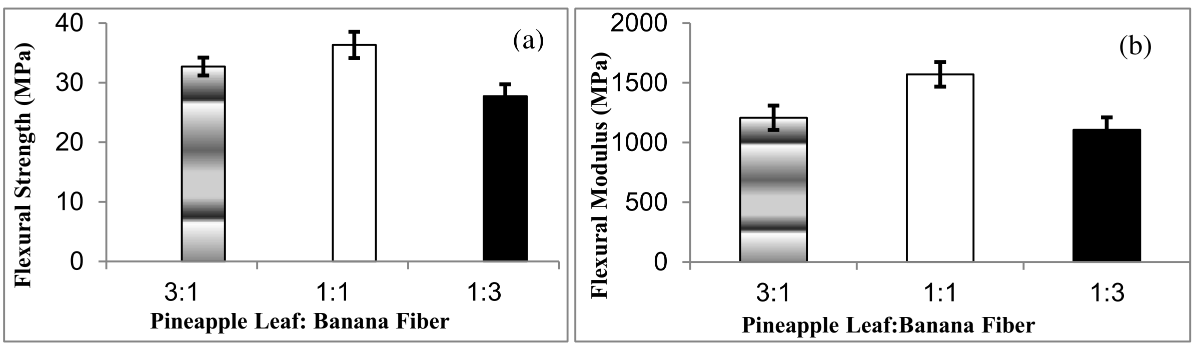

Figure 2. Variation of (a) flexural strength and (b) flexural modulus for different fiber ratio.

3.1.3 Hardness results. Variation of hardness of various prepared composites is shown in Figure 3. Hardness of composites containing pineapple leaf and banana at 3:1 was higher as compared to composites containing those two fibers at 1:1 and 1:3 ratios. The reason may be the higher cellulose content of pineapple leaf fiber. The cellulose content is mainly responsible for higher mechanical properties, such as hardness [7, 8].

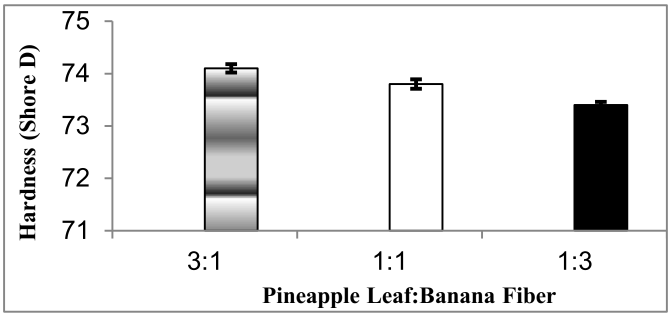

Figure 3. Variation of hardness for different fiber ratio.

3.1.4 Surface morphology. The surface morphology of composites with pineapple leaf and banana fiber at 3:1, 1:1 and 1:3 ratios was observed under scanning electron microscope and is shown in Figure 4. From the SEM images, better bonding is observed for composites containing pineapple leaf and banana fiber at 3:1 ratio as compared to other two composites. The reason is that the pineapple leaf fiber contains higher cellulose and lower lignin as compared to banana fiber. Thus pineapple leaf fiber has higher amount of cellulose exposed on the fiber surface, so it has higher number of possible reaction sites. Pineapple leaf fiber also has lower amount of lignin, wax and oil at the surface, which increases surface roughness. As a result, wetting of the fiber as well as bonding of fiber with matrix improves [9, 10].

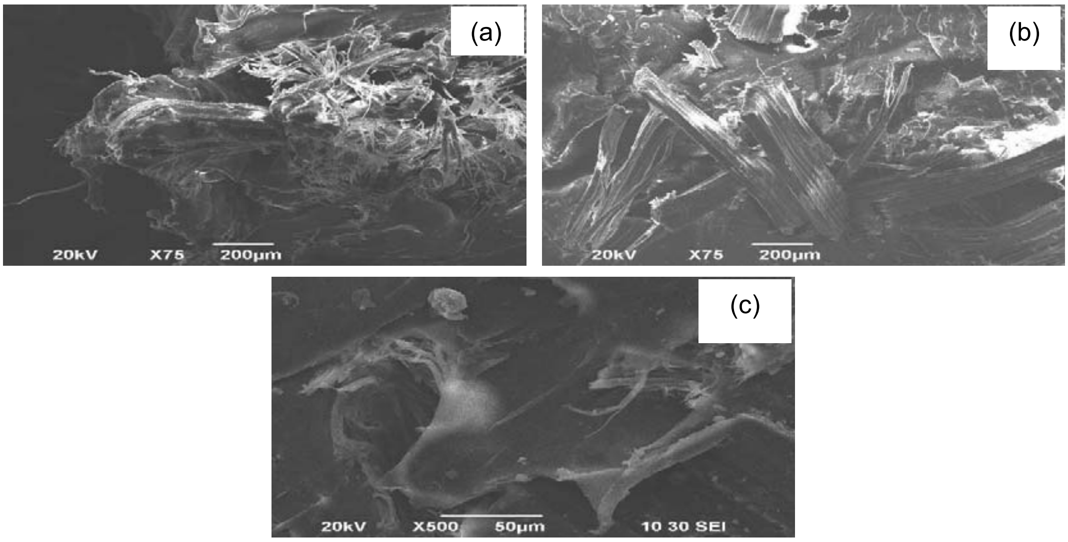

Figure 4. SEM micrographs of composites containing pineapple leaf and banana fiber at (a) 1:3, (b)1:1 and (c) 3:1 ratio.

3.2 Effect of chemical treatment

3.2.1 Tensile properties. Tensile properties of sodium hydroxide (alkali) treated composite was also measured using stress strain curve. Main purpose ofalkali treatment is to disrupt hydrogen bonding in the network structure and remove some hemicellulose, lignin, wax and oils, thereby increasing surface roughness and reducing its hydrophilic nature. During alkali treatment alkali reacts with a cementing material specially hemicellulose, which leads to the splitting of the fibers into finer filaments. This reaction with hemicellulose also increases the amount of cellulose. As a result, wetting of the fiber as well as bonding of fiber with matrix improves [3, 10]. Thus alkali treatment of fibers increased both strength and stiffness of the prepared composites (Figure 5). On the other hand, alkali treatment decreased % elongation at break due to increase in stiffness of respective composite.

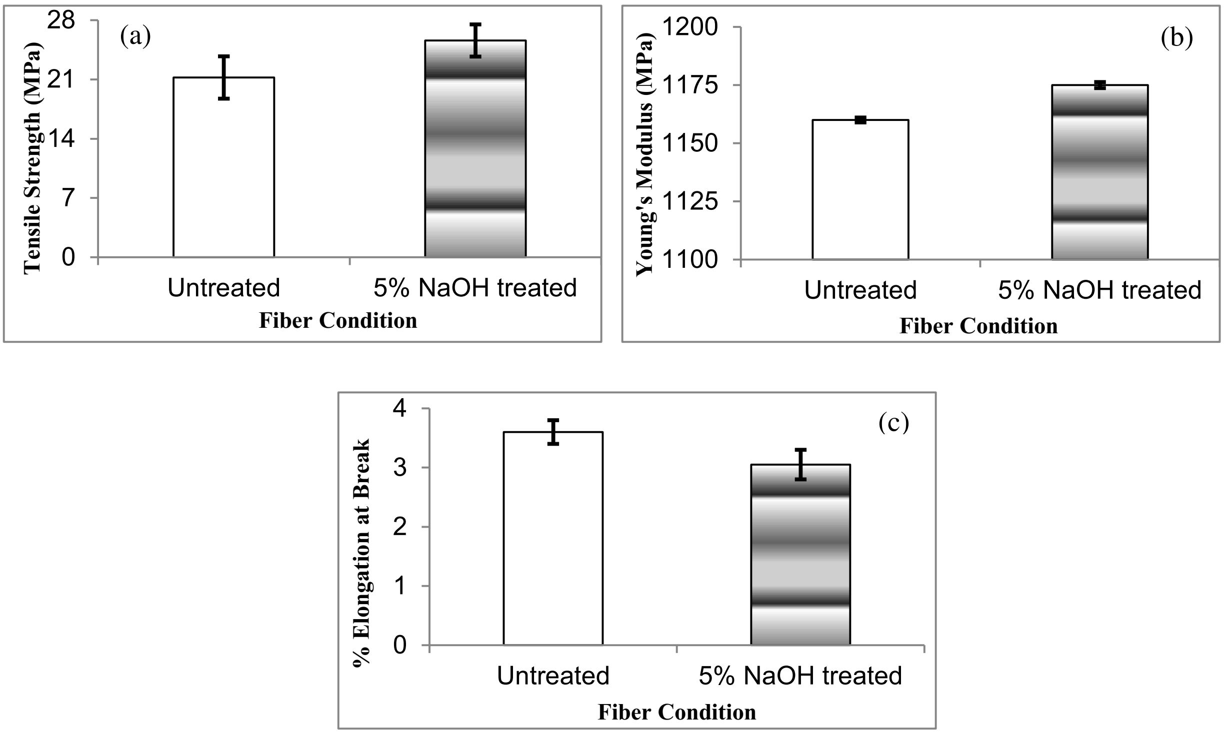

Figure 5. Variation of (a) tensile strength, (b) Young's modulus and (c) % elongation at break with alkali treatment.

*3.2.2 Flexural properties***.** Alkali treatment increases the interfacial interaction between the fiber and matrix.This in turn increases the effective surface area available to contact with the matrix and possibility of load transfer between the matrix and the reinforcing fibers. As a result of flexural strength and modulus increase [10, 11]. Flexural strength and flexural modulus of treated pineapple leaf and banana fiber composites was higher as compared to those of untreated composites (Figure 6).

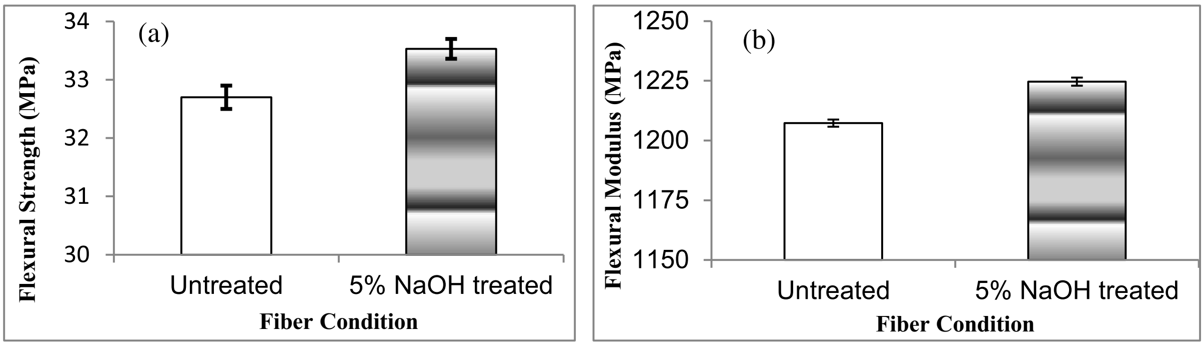

Figure 6. Variation of (a) flexural strength and (b) flexural modulus with alkali treatment.

3.2.3 Hardness results. Alkaline treatment, which was conducted on pineapple leaf and banana fiber resulted inthe collapse of the cellular structure due to the demotion of the cementing material.This in turn led to better packing of cellulose chains and reduction of the void, as well as better adhesion between the matrix and the filler [11]. Thus the interface can transfer pressure more effectively. The hardness value of composite increased with alkali treatment (Figure 7).

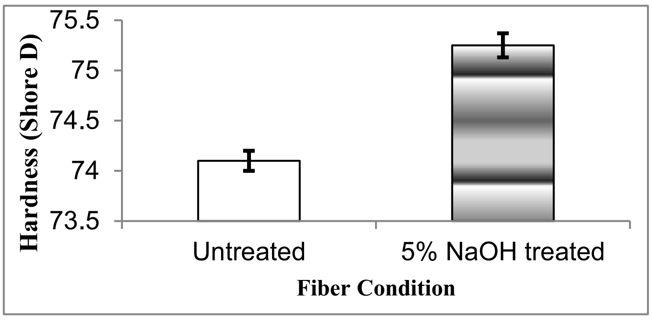

Figure 7. Variation of hardness with alkali treatment.

3.2.4 Surface morphology. Alkaline treatment increases fiber surface roughness resulting in better mechanical interlocking. It also increases the amount of cellulose exposed on the fiber surface, thus increasing the number of possible reaction sites. Also the main purpose of alkali treatment is to disrupt hydrogen bonding in the network structure and remove some hemicellulose, lignin, wax and oils, thereby increasing surface roughness and reducing its hydrophilic nature [12, 13]. SEM micrographs in Figure 8 show better bonding of fiber with matrix in case of treated fiber composite.

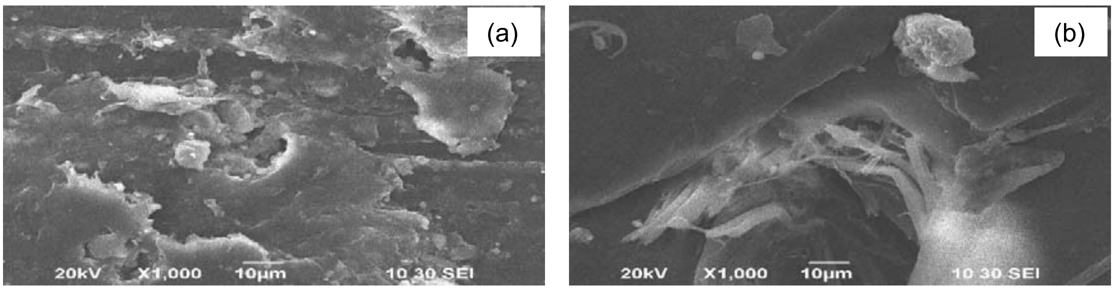

Figure 8. SEM micrographs of (a) alkali treated and (b) untreated fiber composites.

4. Conclusion

In present research, effect of pineapple leaf and the banana fiber ratio and alkali treatment of those fibers on physical and mechanical properties of pineapple leaf and banana fiber reinforced hybrid polypropylene composites are observed. Composites were prepared with pineapple leaf and banana fiber in 3:1, 1:1 and 1:3 ratio and treated pineapple leaf and banana fiber at 3:1 ratio for 5 fiber wt% using hot press machine. Mechanical properties (tensile, flexural, hardness) were higher for 3:1 fiber ratio compositeas compared to the other fiber ratio. SEM micrographs showed better bonding between fiber and matrix in case of 3:1 fiber ratio. Treated fiber composites had better bonding between fiber and matrix and better mechanical properties as compared to untreated fiber composites.

5. References

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