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CHARACTERIZATION OF UNTREATED and ALKALI-TREATED BANANA FIBER, A POTENTIAL REINFORCEMENT IN BIO-COMPOSITES

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ABSTRACT
Banana fiber is one of the easiest available materials in the global scenario. Banana fiber contains high cellulose content. It is better reinforcement material for the preparation of composites. The Alkali treatment method is used as a surface treatment to remove hemicellulose and lignin content. Characterization of fiber is done with the help of different characterization techniques and compares the results of untreated fibers with treated ones. SEM analysis is used for morphological behavior. XRD technique is used to check the crystalline behavior of untreated and as well as treated fiber. TGA analysis is done for thermal degradation of fiber w.r.t temperature. FTIR is used for functional group analysis as the removal of peaks indicates the removal of hemicellulose and lignin content.
Keywords: Banana Fiber, Alkali Treatment, Characterization Techniques, SEM, XRD, FTIR, TGA.
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INTRODUCTION

Natural fiber has been used for the last few years because it has so many benefits over synthetic one. They are renewable, cheap and biodegradable in nature. Classification of natural fiber depends on different parts of plants.[1] sisal, banana, bamboo sisal, hemp, jute and coir, etc. are types of natural fibers. These fibers are available in many parts of the globe.[2] There are different uses of these fibers like for the preparation of ropes and mats and also for fabricating things like tables, table mats, purses, and handbags. For the preparation of clothes banana and cotton fiber is used.[3] Banana fiber is a member of the Musa family. It is extracted from banana trees. The banana trees are too long in nature i.e., approximately 16-17 ft.[4] Banana cultivation produces a large amount of biomass which is transported away as waste.

It can be used in the production of paper, cardboard, tea bags, and banknotes, and as a polymer composite reinforcement in high-quality clothing materials.[5] Pulp of banana fiber is rich in proteins, vitamins, carbohydrates and water. Banana fiber exists in many species but only some species can be used for research purposes. It is a very useful plant and includes different parts like a flower, fruit, leaf, stalk, peel and pseudo-stem. Pseudo-stem is used in pulp and paper industries and also fiber for textiles etc. peels and other things are used for medical purposes.[6] Banana fiber is available in India as well as in African countries. The production of banana fiber in India is approximately 33% while in China it is 12%, Brazil 10%, Mexico 3% and also exits in other different countries.

In 2011, the annual production was 99.99 million tons.[7] This fiber is rich in cellulosic content and which ranges from 55-70%, hemicellulose content very from (10-19%) and lignin content is approximately (5-10%). the ranges are different from different literature. Production of banana fiber is approximately 70 million metric tons per year.[8] Banana fiber is extracted from banana plants with different methods. A decorticator machine is used for the extraction process of fiber.[9]

The preparation of banana fiber composites can be done with a combination matrix. Two types of matrix can be used for reinforcement: thermoplastic and thermosets. Polypropylene, polyvinyl chloride, LDPE and HDPE can be used as a thermoplastic material. There are huge advantages for banana fiber reinforcement with thermosets over banana fiber with thermoplastic material[10].

The combination of banana fiber reinforcement with thermosets matrix enhances mechanical properties like tensile, flexural and impact strength as there is crosslinking occurs between thermosets matrix, so thermosets give better strength than thermoplastic one[11].

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EXPERIMENTAL

Materials and Methods

The Banana fiber was purchased from Go Green Products Chennai. Fibers were dried in ambient condition and cut to approx. 5 mm before using it. All the chemicals used here were purchased from the local market. In this treatment cut fibres were soaked into NaOH solution with different wt. % concentrations of water at room temperature for 2 hr, 1:20 fiber-to-liquor ratio was maintained. To remove impurities from fibres, distilled water was used. For the removal of moisture, a hot air oven was used. Fibers were placed in them for the time off of 48 hours at a constant temperature of 80˚C. This is known as treated fiber. Equation (1) shows the reaction with NaOH. Figure-2 and 3 indicate untreated and treated banana fiber.[12]

$$\text{Fiber-OH} + \text{NaOH} \rightarrow \text{Fiber- ONa} + H_2O \quad (1)$$

Fig.-2: Untreated Banana Fiber

Fig.-3: Alkali Treated Banana Fiber

Characterization of Banana Fiber

Characterization of banana fiber is done with the help of different characterization techniques. Characterization is done for both treated and untreated fiber[13]. FTIR analysis is used for the identification of functional groups in untreated fiber and removal of peaks after alkali treatment of fiber. SEM analysis is used for cross-section and surface morphology of banana fiber. TGA represents thermogravimetric analysis and DTG indicates Derivative thermogravimetric Analysis[14].

RESULTS AND DISCUSSION

FTIR

FTIR analysis of both treated and untreated fiber is shown in Fig.-4 and 5. MB-3000 from the PIKE instrument is used for FTIR analysis. Different types of functional groups like ester, ketenes and aromatics are present in the biomass.[15] The O-H stretching present at 3348 cm^{-1} and C–O–C stretching at 1,027 cm^{-1} is the characteristic of lignocellulosic fiber in the untreated fiber.[16]

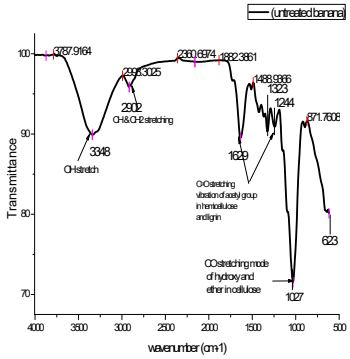


Fig.-4: FTIR Analysis of Untreated Banana Fiber

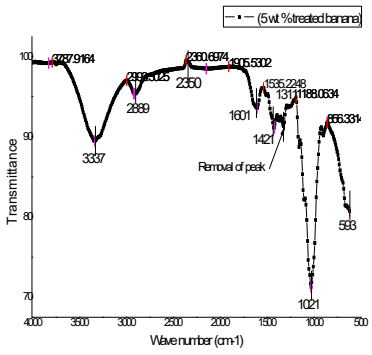
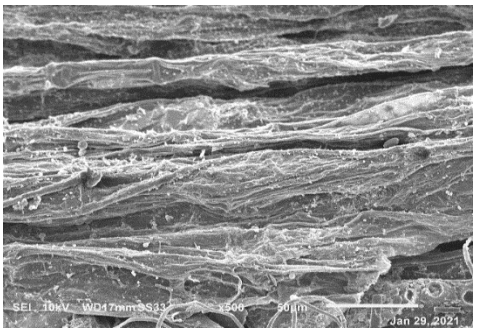


Fig.-5: FTIR Analysis of Treated Banana Fiber

In the case of untreated fiber presence of lignin occurs at the band of 1488 cm^{-1}. The presence of the acetyl group confirms at the carbonyl band with the C=O stretch at 1629 cm^{-1}. The presence of OH group occurs at a band range of 3,600–3,000 cm^{-1} which is related to the hydrophilic tendency of untreated fiber. Carboxylate group presence confirms at band 1535 cm^{-1} which is due to the turning moment of absorbed water.[17]

SEM

64100JSM-6010LA Analytical Scanning Electron Microscope is used for SEM analysis. Surface characterization for untreated fiber is different as shown in Fig.-6. A regular structure with discrete net fibrils is shown in unprocessed banana fiber[18]. Wax, Lignin and hemicellulose present uniform morphology for untreated ones. The SEM image of the untreated fiber cross-section showed a lumen around the cell wall. For untreated fibers, the shape of the lumen is almost oval[19].



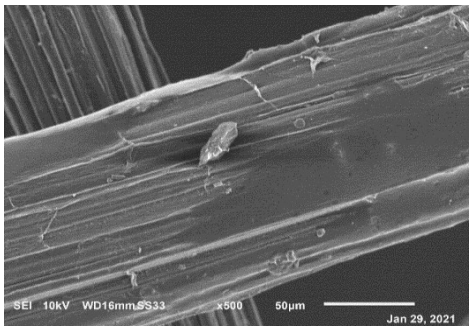
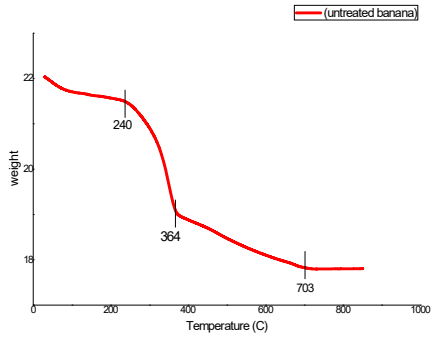


Fig.-6: (a) Untreated banana Fiber (b) Treated banana fiber

TGA and DTG

TGA 4000 thermogravimetric Analyzer is used for TGA Analysis. TGA curves are shown in Fig.-7 and 8 for untreated and treated fiber. The sample is heated from 30.00°C to 850.00°C at 10.00°C/min[20].



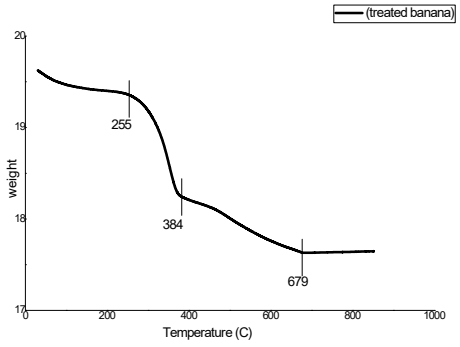
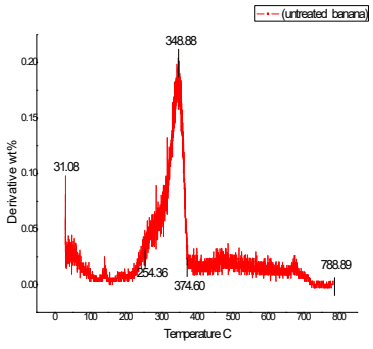


Fig.-7: TGA of Untreated Banana Fiber Fig.-8: TGA of Treated Banana Fiber

In the case of untreated fiber, the first peak corresponding to the water loss appears at 51°C, and the degradation is 0.54%. For untreated fiber, the decomposition occurs at 240-364°C corresponding DTG curves are also shown in Fig.-9 and 10.



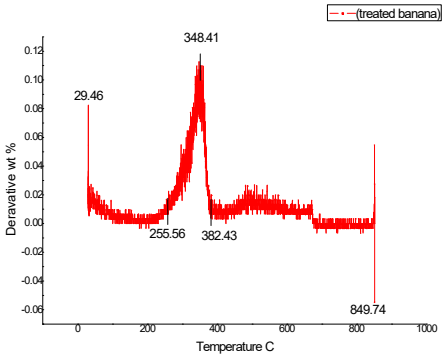


Fig.-9: DTG of Untreated Banana Fiber Fig.-10: DTG of Treated Banana Fiber

The original fiber degrades by 14% at 364°C. This is due to the loss of depolymerization of cellulose and hydroxyl. The final stage of degradation occurs at 364–703°C, due to the decomposition of lignin and the corresponding peak at the DTG curve is observed at 348°C. Lignin is difficult to decompose as it is a macromolecule component.

XRD

A Panalytical X-Pert Powder machine is used For XRD Analysis. Cellulose content is identified at a broad peak at 2theta-21.9˚. 58% is the crystallinity index of untreated fiber and 75% for alkali-treated one, which indicates improvement by the removal of lignin and hemicellulose content. Figure-11 and 12 show the XRD patterns of the untreated fiber and alkali-treated fiber[21]. Two Peaks were identified in the directions of 15.92˚ and 23.4˚. Banana fiber shows crystalline and amorphous phases. 60% indicates for crystalline phase and 40 % for untreated one due to Hemicellulose and lignin phase.

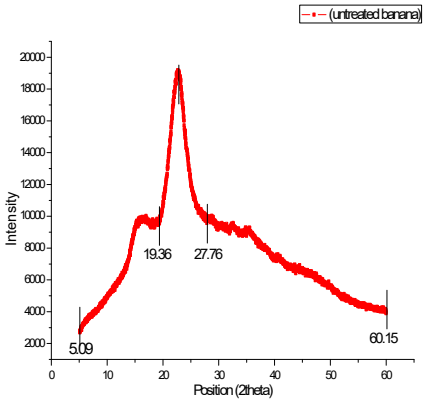


Fig.-11: XRD of Untreated Banana Fiber

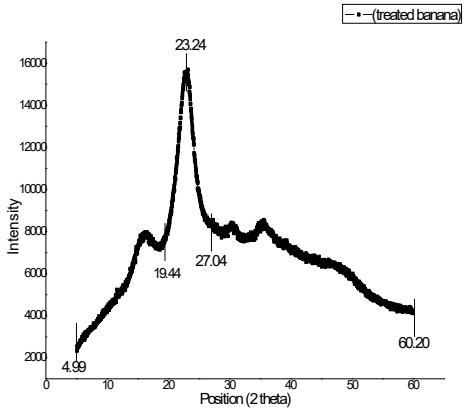


Fig.-12: XRD of Alkali Treated Fiber

CONCLUSION

Banana fiber is characterized by different techniques morphologically, thermal and chemically. Alkali treatment is the best surface treatment method as it is easy and economical. The SEM method is used for morphological behavior. TGA is used for thermal behavior and it is concluded that the temperature degradation range increases in the case of treated fiber. Crystallinity is observed by the XRD method. It is concluded from both the untreated and treated fiber from different characterization techniques that treated fiber is the best reinforcement for the preparation of composite. So for better results, treated banana fiber is used as reinforcement material for the preparation of composites.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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