EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING
Volume 7, Issue 4, 2022: 279-283 | www.ejmse.ro | ISSN: 2537-4338

DOI: 10.36868/ejmse.2022.07.04.279

INFLUENCE OF CHEMICAL TREATMENT ON THE MECHANICAL PROPERTIES AND MORPHOLOGY OF MUSA PARASIDICA FIBER (PLANTAIN)

Sunday Gbenga BORISADE[1,*], Isiaka Oluwole OLADELE[2], Oyetunji AKINLABI[2]

[1]Department of Materials and Metallurgical Engineering, Federal University Oye, Nigeria.
[2]Department of Metallurgical and Materials Engineering, Federal University of Technology, Akure, Nigeria.

Abstract

By substituting various kinds of cellulosic fibers with synthetic ones, it is possible to create composites that are better for the environment. Pinewood, coir, sisal, plantains, abaca, and banana fibers are all suitable sources of material. The strength of adhesion between the matrix polymer and fiber is the most crucial element in finding appropriate fiber reinforcement in composites. Plantain (Musa parasidica) fibers were treated with an alkaline solution at various concentrations for varying soaking times. An Instron testing machine and a scanning electron microscope (SEM) were utilized to determine the effect of this chemical alteration on the mechanical characteristics and surface morphology of the fiber. Following treatment, fibers had an improved surface roughness and reached an optimal tensile strength of 651MPa, according to micrographs taken with a scanning electron microscope.

Keywords: *Natural fiber; chemical treatment; plantain fiber; mechanical characteristics; alkaline.*

Introduction

Natural fibers have been rudimentary used informally throughout history to meet human needs, such as in the production of sacks, ropes, bags, rugs, floor coverings, carpet backs, binder twines, hats, mats, and stuffing material for mattresses and furniture. This is because they are less expensive, have a higher toughness than synthetic fibers, are non-toxic, recyclable, and are more readily available [1]. Due to well-established ecological factors, natural fiber has recently seen a rise in popularity for a variety of applications as potential resources for the creation of composite materials. Due to their superior mechanical performance, natural fiber reinforced plastic composites are gaining popularity quickly [2]. Preventing the loss of forest resources and guaranteeing high returns on investment are the two main philosophies on which the manufacture of natural fiber composites is based [3].

Plastics are a vital component of contemporary economies and are widely employed in a wide range of industries, including food packaging, electronics, aerospace, and more. However, it has proven to be difficult to dispose of solid wastes that contain plastics. Solid waste management has emerged as a pressing environmental concern worldwide, particularly with regard to waste polymers made from petroleum. Therefore, in an effort to replace conventional plastic, governments and researchers from all over the world have stepped up their efforts to create unique biocomposites that either use natural polymer as the matrix or reinforcement [4]. Biocompatible and/or environmentally friendly composites, such as proteins and polysaccharides, are referred to as biocomposites.

*Corresponding author: sunday.borisade@fuoye.edu.ng

Natural fiber reinforced polymer composites are significant research topics in contemporary science and technology because they have an improved modulus and are lighter than other conventional engineering materials like wood, metal, and steel. They can also assist industries in moving toward more carbon-neutral production due to their special strength properties, availability, light weight, ease of separation, improved energy recovery, and high resilience. Composites are structural materials that are macroscopically combined from two or more non-soluble elements [3, 4].

Different kinds of plants naturally produce natural fibers. Lignocellulosic fibers (flax, hemp, sisal, etc.), protein fibers (wool, silk, chitin, etc.), and mineral fibers (asbestos, etc.) are the three categories into which natural fibers can be divided [5]. In addition to being biodegradable and renewable, natural fibers (NF) also have good mechanical qualities that make them a better choice for reinforcement than conventional fibers and polymers. These qualities include high modulus, high specific strength and stiffness, safe manufacturing processes, low cost, and lightweight. Little energy is needed for the manufacture, and while CO2 is used, oxygen is returned to the environment. It is generated at a minimal cost and with little investment, which makes the content entertaining and predictable for nations with low wages. Unlike glass, which presents issues in combustion furnaces, thermal recycling is viable and can be treated ethnographically without wearing down or irritating the skin. They are now being utilized or are anticipated to be used widely for composite materials due to their good thermal and acoustic insulating characteristics. High moisture absorption, poor wettability, incompatibility with various polymeric matrices, inferior strength qualities, especially its impact strength, and other issues are major drawbacks of natural fiber compared to synthetic fiber. Researchers have over the years advised using physical and chemical treatments for surface modification to address these issues and enhance the qualities of natural fibers as a way to do so. Several publications have reported on the impact of these modifications on the tensile, surface morphology, thermal behavior, and structure of natural fibers [6, 7].

The results have demonstrated that great thermal stability, increased tensile strength, increased stiffness, and changes in macromolecular and crystallographic structure were all detected following treatment with potassium permanganate (KMn04), demonstrating the effectiveness of this method [8]. Alkali treatment, also known as mercerization, is a chemical procedure that involves submerging natural fibers in a concentrated aqueous solution of strong base to produce enough swelling by removing hemicelluloses, lignin, waxy substances, and contaminants from the surface of the fiber cell wall. Natural fibers treated with alkali improve in tensile strength, fibrillation-induced fibre wetting, and matrix adhesion as a result of the elimination of natural and synthetic contaminants as well as oils from the cell wall's exterior surface. The native cellulose structure is depolymerized by alkaline solution, exposing short-length crystallites. According to published research, alkaline treatment of fibers results in the depolymerization of cellulose as well as an increase in the fiber's surface roughness, which in turn leads to a greater extension of hydrogen bonds at the fiber-matrix interface [9].

Natural fibers are made of cellulose and lignin from plants. Plantain fiber is a bast lignocellulosic fiber that can be extracted from the pseudo-stem of the plant after the fruits and leaves have been used. Bast fibers are fibers that contain lignin, hemicellulose, and cellulose in varying proportions as well as minerals, wax, water soluble compounds, and pectin that acts as glue to hold the fibres together as bundles. During retting, the pectin, gum, and other mucilaginous materials present in the bundles are broken down, assisting in the extraction of the fiber [9]. In West Africa, the plantain (Musa paradisiaca) is a common cultivar. Nigeria is also one of the world's top producers of bananas and plantains. The plant only produces one fruit during its lifetime. Plantains have strong, tall stems and a succulent leaf. The pseudo-stem is a 7.5 m tall cylindrical stem with long fibers and highly overlapping leaf-petiole sheaths. [2]

Natural fiber is one of the ecologically friendly materials that are being taken into consideration for the majority of applications due to their superior qualities when compared to synthetic fiber in terms of eco-relationship [10]. Utilizing materials that are waterproof, moderately strong, and corrosion-resistant, natural fiber is used in the majority of technical components for the production of cars, aircraft, home appliances, and packaging. Global industry researchers predicted that the global market for natural fibers would be worth $6.4 billion by 2022 and rise at a compound yearly growth rate of 10.2% from 2022 to 2026. The purpose of this work is to assess the effects of chemical modification on the fiber surface of plantain by employing some of the common treatments for natural fibers (Musa paradisiaca). These steps are intended to separate the technical fibers from the non-structural fibers in the fiber bundles. How these changes affect the plantain fiber that is extracted and whether the resulting fibers will have increased stiffness and strength as potential reinforcement for polymer matrices.

Materials and Methods

Following the harvest season, plantain (Musa paradisiacal) pseudo stem were gathered from a nearby farm in Ekiti state, south-western Nigeria and the fiber was extracted using dew ratting techniques, according to [7], [9]. The treatment applied to the fiber was described in Table 1 with the untreated fibers being classified as UTP.

Using a JEOL JSM-T330A scanning electron microscope and an accelerating voltage of 20 KV, SEM images of untreated and alkali-treated plantain fibers were captured.

Alkaline fiber treatment

The extracted fibers were treated with compositions of 1 %wt. and 3 %wt. sodium hydroxide solution. Fibers were soaked for varying lengths of time 1 hours to 4 hours. After removing the fibers from the solution, they were repeatedly rinsed with distill water.

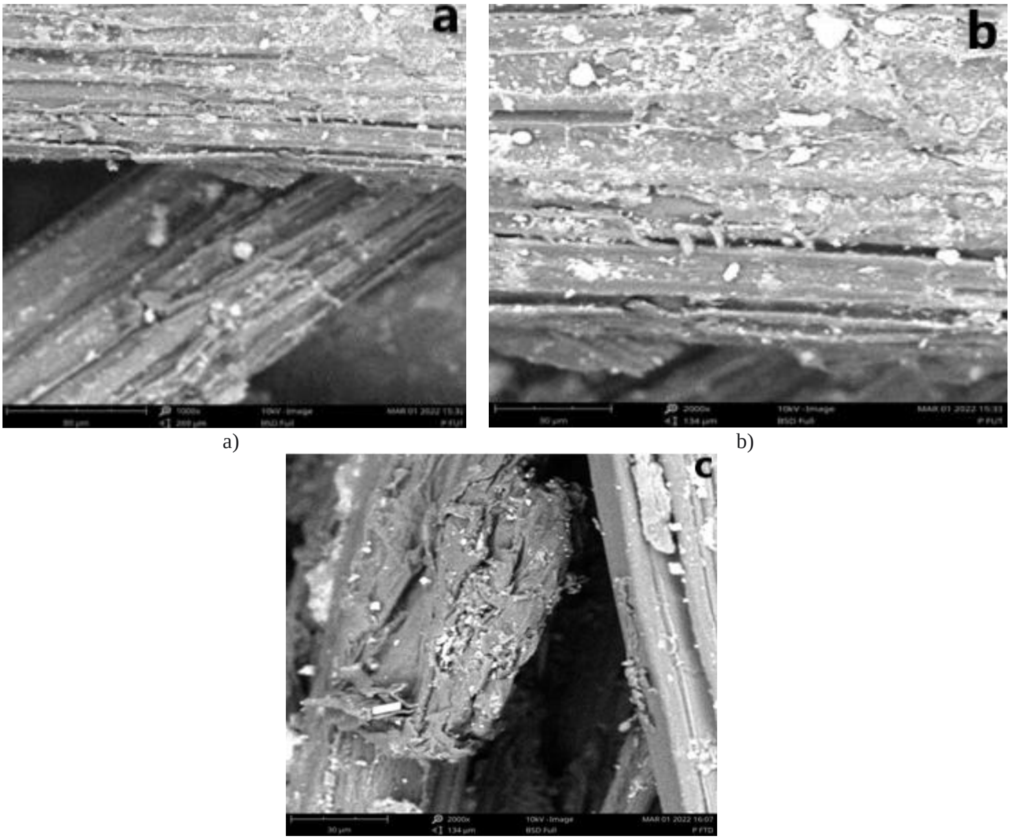
PH paper was used to verify the fibers' neutrality. The fibers were dry for 24 hours at ambient temperature, and then for 5hours. They were placed in an air-circulating oven at 50 °C to achieve constant weight. INH1, 3NH1, and 1NH4 were assigned to the fibers. The suffixes of "NH" signify the number of hours that the fiber was immersed in the solution, whilst the prefixes of "NH" indicate the alkaline solution's concentration in water before being washed with extremely diluted acetic acid to remove any remaining alkaline.

Table 2. The characteristics of the raw materials

Sample	Density (g/cc)	Young's Modulus (GPa)	Tensile Strength (MPa)	Elongation at break (%)
UTP	1.334	8.05	489.54	3.27
1NH1	1.362	8.87	538.49	3.60
1NH4	1.441	10.06	611.93	3.89
3NH1	1.393	8.78	533.60	3.56
3NH4	1.530	11.51	651.09	4.02

Morphological Study

Figure 1 displays SEM micrographs of untreated and treated fiber (a-c). In the untreated fiber, it was seen that the surface was smooth and covered in waxes and other contaminants. With an increase in alkaline solution concentration from 1% to 3%, the fiber's surface roughness increased. This might be as a result of the limited removal of hemicellulose, lignin, and significant removal of surface contaminants from the fiber, which gave the fiber a rough surface and increased the prominence of the fibrous region. The fiber with the roughest surface after being exposed to alkaline was 3N4 fiber. The SEM of fibers treated showed that the fiber becomes rough and brittle.



a) b) c)

Fig. 1. Longitudinal morphology of plantain fibers (a) UTP (b) 1NH4 (c) 3NH4

Conclusion

Effect of alkaline treatment has examined the influence of chemical treatment on the mechanical characteristics of natural fiber isolated from plantains (Musa paradisiacal).

Macromolecular parameters of the fibre along with crystallographic structures and morphology of the fibre were all affected by the chemical modification. Significantly removing surface contaminants, surface morphology demonstrates that chemical treatment increases fiber roughness. In general, chemical treatment has significantly enhanced the plantain (Musa paradisiacal) fiber's mechanical qualities and increased the fiber's resin permeability when utilized as composite reinforcement.

Acknowledgements

This research was supported by Mr. Owoeye Seun from Federal Polytechnic Ado, Nigeria. I thank my colleagues from Federal University Oye –Ekiti who provided insight and expertise that greatly assisted the research.

References

[1] E. C. Okafor, C. C. Ihueze, *The Graft of ANN-FEM Technique in Macro-mechanics of Multi-oriented Natural Fiber/Polyester Laminates*, **Mechanics of Advanced Composite Structures, 8**, 2021, pp. 51-68.

[2] A. G. Adeniyi, S. Abdulkareem, M. Ndagi, M. T. Abdulkareem, J. Ighalo, *Effect of fiber content on the physical and mechanical properties of plantain fiber reinforced polystyrene composite*, **Advances in Materials and Processing Technologies**, 2022, pp. 1-3.

[3] R. S. Odera, O. D. Okechukwu, E. M. Ezeh, M. C. Menkiti, P. C. Agu, *The exchange of Musa spp. fbre in composite fabrication: a systematic review*, **Bulletin of the National Research Centre**, **45**, 2021, pp. 1-2.

[4] R. Venegas , A. Torres , A. M. Rueda, M. A. Morales, M. J. Arias, A. Porras, *Development and Characterization of Plantain (Musa paradisiaca) Flour-Based Biopolymer Films Reinforced with Plantain Fibers*, **Polymers**, **14**, 2022, pp. 1-4.

[5] M. M. Rashid, S. A. Samad, M. A. Gafur, A. M. S. Chowdhury, *Study of Different Chemical Treatments for the Suitability of Banana (Musa oranta) Fiber in Composite Materials*, **International Journal of Scientific & Engineering Research**, **6(4)**, 2015, pp. 1870- 1871.

[6] P. E. Imoisili, O. B. Fadare, A. V Popoola, A. E. Okoronkwo, *Effect of Chemical Treatment on the Morphology and Mechanical Properties of Plantain (Musa paradisiaca) Fiber*, **IOSR Journal of Applied Chemistry (IOSR-JAC)**, **10(5),** 2017, pp. 70-73.

[7] P. E. Imoisili, S. O. O. Olusunle, A. V. Popoola, A. E. Okoronkwo, *Effect of Alkaline Treatment on the Macromolecular, Thermal, and Crystallographic Structures of Plantain (Musa paradisiaca) Fibers*, **Plaintain fibre treatments, 6(2)**, 2017, pp. 88-97.

[8] P. E. Imoisili, I. T Dagogo, A. V Popoola, A. E. Okoronkwo , *Effect of High-frequency Microwave Radiation on the Mechanical Properties of Plantain (Musa paradisiaca) Fibre/Epoxy Biocomposite* , **Journal of Physical Science**, **29(3)**, 2018, pp. 23–35.

[9] A. G. Adeniyi, D. V. Onifade, J. O. Ighalo, S. A. Abdulkareem, M. K. Amosa, *Extraction and Characterization of Natural Fibres from Plantain (Musa paradisiaca) Stalk Wastes*, **Iranian (Iranica) Journal of Energy and Environment**, **11(2)**, 2020, pp.116-121.

[10] I.O. Oladele, T. F. Omotosho, G. S. Ogunwande, F. A. Owa, *A Review on the Philosophies for the Advancement of Polymer-based Composites: Past, Present and Future Perspective*, **Applied Science and Engineering Progress**, 2021, pp. 1-27

[12]. I. M. De Rosa, J. M. Kenny, D. Puglia, C. Santulli, F. Sarasini, *Morphological and thermal characterisation of okra (Abelmoschus Esculentus) fibers as potential reinforcement in polymer composites.* **Compos Sci Technol**, **70(1)**, 2010, pp.116–122.

[11]. G. Wolfgang, K. J. Martinschitz, P. Boesecke, J. Keckes, *Structural changes during tensile testing of an all-cellulose composite by in situ synchrotron X-ray diffraction*, **Composite Science Technology**, **66**, 2006, pp.2639–2647.

Received: September 09, 2022
Accepted: October 12, 2022