

Effect of Chemical Treatment on the Morphology and Mechanical Properties of Plantain (*Musa paradisiaca*) Fiber

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Abstract : Natural fiber extracted from Plantain (*Musa paradisiaca*) fibers were treated with alkaline and potassium permanganate ($KMnO_4$)—acetone solution at various concentrations for different soaking time. In order to identify the effect of this chemical modification on the mechanical properties and surface morphology of the fiber, Instron testing machine and Scanning Electron Microscope (SEM) was used. Mechanical properties test results reveals that chemical treatment substantially improve the strength of treated fiber and increase its bulk density. Optimum tensile strength of 690Mpa was obtained after treatment; while Scanning Electron Microscope (SEM) micrographs indicate enhance surface roughness of treated fibres. Treated Fibres with 0.05% $KMnO_4$ -acetone solution for 3min (05K3) was found to have the highest tensile strength, enhance uniform surface roughness, and bulk density.

Key words: Alkaline, Mechanical properties, Natural fiber, Plantain fiber, Potassium permanganate

I. Introduction

Natural fiber (NF) can be divided into plants, which composed of cellulose, animal or minerals which consist of proteins [1]. Natural fibers (NF) are not only biodegradable and renewable but possess some unique advantages over conventional fiber such as high modulus, high specific strength, safe manufacturing process, low cost, lightweight and high strength [2-3]. Major disadvantages of Natural Fiber in comparison with synthetic fiber are high moisture absorption, Poor wettability, incompatibility with some polymeric matrices etc [4]. To overcome these challenges, researchers have over the years suggested the use of physical and chemical treatments for surface modification as a way of overcoming these challenges and improving the properties of natural fibers [2-4]. The effect of these modification on the tensile, surface morphology, thermal behavior and structure of natural fibers has been reported by various authors [2- 9].

The fiber from the plantain empty fruit bunch that are nowadays disposed as an unwanted waste, might be seen as a recyclable potential alternative to be used in polymeric matrix composite material [4-6]. The plantain plant (*Musa Spp*) is a multivalent fiber producer, its fibers can be extracted from any part of the plant including the long leaf sheet and the pseudo-stem [5]

The use of potassium permanganate ($KMnO_4$) as chemical modification for some natural fiber has been proven to be very effective [5], as results has shown that high thermal stability [6], increase tensile strength [7], increase stiffness [7-10], changes in macromolecular and crystallographic structure were all observed after treatment [11]. Alkaline treatment of natural fiber also improves the tensile strength, fiber wetting by fibrillation, fiber-matrix adhesion due to the removal of both natural and artificial impurities, and oils covering the external surface of the fiber's cell wall, depolymerizes the native cellulose structure and exposes short length crystallites [12].

This work is aimed at evaluating the effect of chemical modification on plantain (*Musa paradisiaca*) fiber surface by applying some of the usual treatments for natural fibers. These actions are intended primarily on the fiber bundles, to isolating the technical fibers and removing non-structural matter from them. A subsequent objective would be evaluating the effect of these modification on extracted plantain fiber, whether the resulting fibers would obtain improve strength and stiffness as potential reinforcement for polymer matrices.

II. Materials and Methods

Plantain (*Musa paradisiaca*) pseudo stem were collected from a local farm in south west Nigeria state of Ondo after the harvest season and the fiber were extracted using water retting methods as reported by Paridah et al [13]. The untreated fibers were designated as UT, treatment applied to fiber were reported in Table 1

Alkaline Treatment of Fiber

The extracted fibers were immersed in the solution of 1% and 3% of sodium hydroxide solution. The soaking period of fibers were varied for 1hrs and 4 hrs. Then the fibers were taken out from the solution, rinsed with distilled water several times and finally wash with very dilute acetic acid to remove the residual Alkaline.

Neutrality of the fibers was checked by PH paper. The fibers were dried at room temperature for 24 hours, after which the fibers were placed in an air circulating oven at 60°C, for 6 hours until the fiber gets constant weight. The fibers were designated as 1N1, 1N4, 3N1 and 3N4. The prefixes of 'N' denote the concentration of the alkaline solution whereas the suffixes of 'N' represent the immersion time of the fiber in the solution in hours.

Permanganate Treatment of Fiber

The extracted fibers were treated as described by Annapurna et.al. [10]. KMnO₄-acetone solution having concentration of 0.01% and 0.05%, was used to treat the fiber for a period of 1 and 3 minutes each, after which the solution was decanted and the fibers washed with acetone to remove excess solution present in the fibers. Finally, the fibers were dried at 60°C in a vacuum oven for 12 hrs. Untreated fiber was denoted as UT and treated fibers are designated as 01K1 01K3, 05K1 and 05K3 respectively. Here K symbolizes to KMnO₄ treatment. The prefixes of K denote the concentration of KMnO₄ acetone solution i.e. 01, 05, for 0.01% and 0.05% concentrations respectively. However, the suffixes of K denotes the soaking time for the fibers in the solution in minutes.

Table 1: Chemical Treatment applied on plantain fiber

Categories	Chemical Treatment
UT	Untreated plantain fibers
1N1	1% sodium hydroxide solution for 1 hour
1N4	1% sodium hydroxide solution for 4 hour
3N1	3% sodium hydroxide solution for 1 hour
3N4	3% sodium hydroxide solution for 4 hour
01K1	0.01% KMnO ₄ -acetone solution for 1 minutes
01K3	0.01% KMnO ₄ -acetone solution for 3 minutes
05K1	0.05% KMnO ₄ -acetone solution for 1 minutes
05K3	0.05% KMnO ₄ -acetone solution for 3 minutes

Mechanical Properties of Fiber

Tensile tests were carried out on both untreated and treated fibers according to ASTM D 3822 at room temperature on a universal Instron testing machine model 3369, with 25 N as load cell full range. Fibers were tested in the as-received state at a gauge length of 10 mm in displacement control and at a crosshead speed of 1 mm/min. Density measurements of treated and untreated fibers were done as per ASTM D3800-99. Untreated and treated plantain fibers were examined under a Zeiss Gemini Scanning Electron Microscope (SEM) to see the effect of chemical modification on their surface properties.

III. Results and Discussions

The mechanical properties of treated and untreated plantain fiber are reported in Table 2. Plantain fibers exhibit the single linear elastic deformation until failure with no plastic deformation, which is typical of vegetable fibers [14]. Test results reveal that both modification has greatly improve the tensile strength, young's modulus and density of the fiber, it was also observed that permanganate treatment of 0.05% for 2 minutes gave the superior tensile strength and young's modulus. Chemical modification of plantain fiber has also resulted in reduction in crystal defect and distortion after treatments, thus lead to increase in bulk density of the fibers [10]

Table 2: Various crystallographic and physical parameters of for Untreated and KMnO₄ Treated Fibers

Sample	Tensile Strength (Mpa)	Young's Modulus (Gpa)	Elongation at break (%)	Density (g/cc)
UT	489.54	8.05	3.27	1.334
1N1	538.49	8.87	3.60	1.362
1N4	611.93	10.06	3.89	1.441
3N1	533.60	8.78	3.56	1.393
3N4	651.09	11.51	4.02	1.530
01K1	523.81	8.61	3.50	1.372
01K3	675.57	11.59	4.07	1.359
05K1	543.39	8.94	3.63	1.353
05K3	690.25	13.28	4.40	1.544

SEM micrographs of untreated and treated fiber are shown in Fig. 1(a-e).it was observed in the untreated fiber (Fig 3a), that the fiber surface was smooth, covered with waxes and other impurities. The surface roughness of the fiber was increased with increase in concentration of alkaline solution from 1% to 3% this may be due to the partial removal of hemicellulose; lignin and substantial removal of surface impurities from the fiber hence provided a rough surface to the fiber and the fibrous region became more pronounced. Maximum surface roughness for alkaline treated fiber was observed for 3N4 fiber. The SEM of permanganate treated fibers revealed that the fiber becomes rough and fibrillated, increase in KMnO₄ treatment also resulted in increases of

fiber roughness. 05K3 fiber showed uniform surface roughness of the fiber. This might be due to the effective oxidation of the fiber surface when it is soaked in 0.05% of concentration of $KMnO_4$ – acetone solution for 3 min which lead to the better roughness of the fiber due to the removal of lignin, waxy material along with the impurities from the fiber

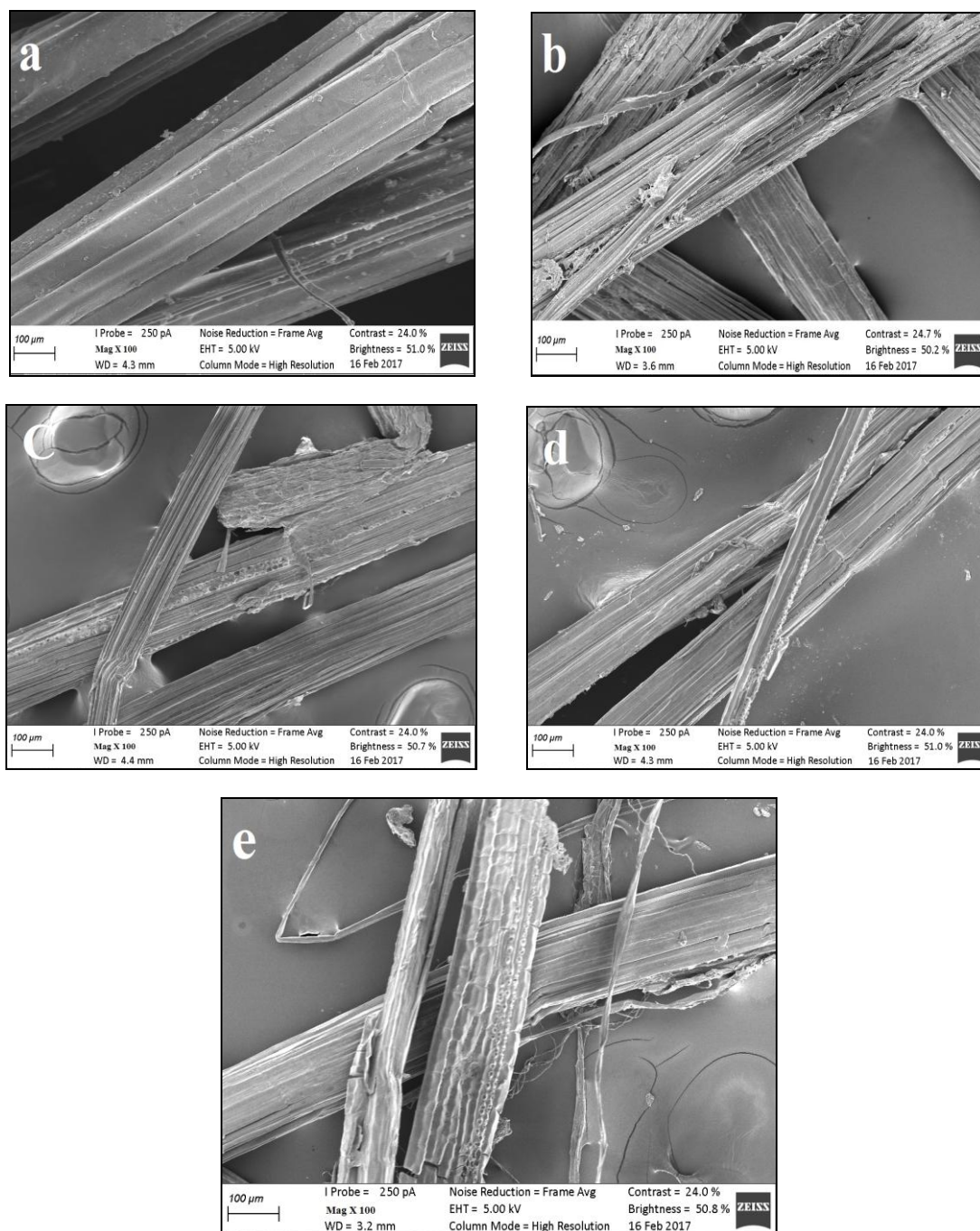


Figure 1: Longitudinal morphology of plantain fibers (a) UT (b) 1N4 (c) 1N4 (d) 01K3 (e) 05K3

IV. Conclusion

The effect of chemical treatment on the mechanical properties of natural fiber extracted from Plantain (*Musa paradisiaca*) has been studied using alkaline and potassium permanganate. Results obtained show that permanganate treated fibers have superior tensile strength, young's modulus than that of alkaline treatment. Surface morphology shows that chemical treatment increases fiber roughness by the substantial removal of surface impurities. As a general point, chemical treatment has substantially improved the mechanical properties of Plantain (*Musa paradisiaca*) fiber and thus makes the fiber more permeable to resin when used as composite reinforcement,

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