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Effects of Surface Modification on the Mechanical Properties and Water Absorbtion of *Raphia farinifera* (Raphia Fibre)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The effect of surface modification on the mechanical properties and water absorption of *Raphia farinifera* (raphia fibre) were examined. The fibre was treated with 2% benzoyl peroxide in acetone, 10% potassium hydroxide, 25% hydrogen peroxide and 1% potassium permanganate in one hour. The mechanical properties; tensile strength, load at break, modulus and water absorption properties were investigated and results compared with control (untreated fibre). The results of the mechanical properties showed that the tensile strength of the fibre (*Raphia farinifera*) improved from 50.1142MPa for the untreated fibre to 132.3482MPa for potassium hydroxide treatment and 146.0181MPa for hydrogen peroxide treatment. Benzoyl peroxide treatment showed superior load

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at break value (25.5617N) over the untreated fibre (14.7847N). The results of water absorption showed that the treatment of the fibre reduced the hydrophilic nature of this fibre. However, benzoyl peroxide treatment showed highest reduction in water absorption capacity of the fibre followed by potassium hydroxide treatment.

Keywords: Raphia fibre; mechanical properties; water absorbtion; Cellulosic fibres; Raphia farinifera; benzoyl peroxide; potassium permanganate; potassium hydroxide.

1. INTRODUCTION

Over the last few years a number of researchers have been involved in investigating the exploitation of natural cellulosic fibres as load bearing constituents in composite materials. The use of these materials in composites has increased over the last few years due to the relative cheapness compared to conventional materials such as glass and aramid fibres, their ability to recycle which reduces environmental pollution and their ability to compete well in terms of strength per weight of materials. Currently, a revolution in the use of natural fibres (cellulose fibres), as reinforcement in technical application is taking place mainly in the automobile and packaging industries for example production of egg cases [1,2,3].

These natural cellulosic fibres, however, have certain limitations in their use as reinforcement in composites (e.g. thermoplastics). The major limitations include poor interfacial adhesion between polar-hydrophilic cellulose fibre, and non polar – hydrophobic matrix, in addition, there is difficulties in mixing, due to poor wetting of the fibre with the matrix. This in turn would lead to composites with weak interface [4,5]. Due to the above limitations, it is therefore necessary to modify the fibre surface to render it more hydrophobic and also more compatible with resin matrices. A way of modifying these fibres to render them more hydrophobic is by chemical pretreatments [6,7].

This study was therefore meant to examine the effects of pretreatment with chemicals on the mechanical properties of cellulosic fibres, with a view to reducing the moisture absorption of the fibre and improving its mechanical properties.

This area of research has received increasing attention both by the academic sector and the industry. The abundance of the raw material and the pressure on industries to use evermore “greener” technologies have made this area of research of worldwide interest [8,9]. Conventional and synthetic fibres such as Kevlar and glass fibres used as reinforcement are toxic, have high density, they are abrasive during processing and are non biodegradable. They are high in cost and some have high thermal conductivity. These properties make them environmentally unfriendly and poses difficulty during processing when used as reinforcement in composites.

Cellulosic fibres on the other hand, are biodegradable, non toxic, non abrasive and are abundantly available and accumulated as waste in the environment. Cellulosic fibres possess positive properties and can be used as reinforcement in composites thereby reducing environmental pollution. [10,11]. The aim of this study is to determine the effects of pretreatment on the mechanical properties and water absorption of *Raphia farinifera,* the mechanical properties of raphia farinifera, before treatment, to pretreat this fibre with benzoyl peroxide, potassium permanganate, potassium hydroxide and to determine the effects of pretreatments on the mechanical properties of the fibre and water absorption.

2. MATERIALS AND METHODS

2.1 Sample Collection

Raphia fibre was obtained from a palm tree in Agbor, Delta State. Potassium hydroxide, hydrogen peroxide, benzoyl peroxide, potassium permanganate and acetone were purchased from Poly Consult Ventures (25 Ogunleti Street) Ojota Lagos.

2.2 Apparatus

The apparatus used includes:

Instron Universal Testing Machine: Model 3369, Weighing Balance, Beaker, Water bath and Conical flask

2.3 Treatment of Samples

i. Potassium Hydroxide Treatment

The fibre was immersed in 200ml of 10% Potassium Hydroxide in a 600ml beaker for one hour. The fibre was then washed in distilled water and finally dried, in an oven at 60^{0}C for three hours to a constant weight.

ii. Hydrogen peroxide Treatment

100ml of commercially produce hydrogen peroxide was made up to 400ml with distilled water, the fibre was then immersed into the solution for one hour, after which it was decanted, washed and oven dried at 60^{o}C for three hours to a constant weight

iii. Potassium permanganate Treatment

The fibre was treated by immersing into 1% Potassium permanganate for one hour, after which the solution was decanted, the fibre was washed with distilled water and oven tried at 60^{o}C for three hours to a constant weight.

iv. Benzoyl Peroxide Treatment

The fibre was immersed in 2% solution of benzoyl peroxide in acetone. The sample was placed in hot air oven at 40^{o}C for half an hour to remove acetone from the surface of the fibre, the fibre was then dried to constant weight.

2.4 Characterization of the Samples

2.4.1 Mechanical properties

Test for tensile properties were carried out using the Instron universal testing machine at crosshead speed of 5mm/min. Each tensile specimen was positioned in the Instron universal tester and then subjected to tensile load, as the specimen stretches the computer generates the graph as well as all the desired parameters until the specimen fractures.

2.4.2 Water absorption test

The samples were oven dried at 80^{o}C to a constant weight by weighing with a digital weighing balance with precision of 0.0001 g. and then immersed in a static distilled water. The specimens were taken out of the water at 1hr, 3hrs,6hrs,12hrs and 24hrs interval wiped with tissue paper to remove surface water and weighed. At least three specimens for each sample were used and the average values were used.

The percentage of water absorption (WA) was calculated by the weight difference between the samples exposed to water and the dried samples according to the following equation:

$$\mathrm{WA}(\%) = \frac{Me - M0}{Me} X\ 100$$

Where: *M*e is the mass of the sample after immersion (g)

and *M*o is the mass of the sample before immersion (g).The experiment was conducted in relative humidity (RH) equal to 50 % at 296 ±5.638.

3. RESULTS AND DISCUSSION

The results of the different treatments on the mechanical properties of raphia fibre are shown in Table 1.

From Table 1, the results showed that hydrogen peroxide treated raphia fibre showed superior tensile strength (146.0181MPa) followed by $KMnO_4$ treated (133.7359MPa), and KOH treated (132.3482MPa), with benzoyl peroxide treated raphia fible showing the least tensile strength of 40.9367N. The increase in tensile strength can be attributed to increase in crystallinity of the fibre and removal of amorphous materials. It has been reported that the appreciable enhancement in mechanical properties was found owing to the surface treatment concentration and duration of treatment. While the decrease as observed in Benzoyl peroxide treatmen,t can be attributed to increase in amorphous region of the cellulosic fibre over crystalline region [12,13,14]. A one way ANOVA that was performed to compare the effect of the different treatments on the tensile strength of the raphia fibres revealed that the observed differences in the mean tensile strength were statistically significant in the treatment groups (F (4, 10) = [1189.1], p<.001).

Table 1, Fig. 2a/b untreated raphia fibre showed superior modulus (2473.0627MPa) over treated raphia fibre. However, $KMnO_4$ treated fibre show higher value (7006.8366MPa) than other treated raphia fibre. Excess delignification of the cellulosic fibre, leads to damage of the fibre and hence the reduction in the modulus this is as reported by Oushabi et al [13]. A one-way ANOVA that was performed to compare the effect of the different treatments on the modulus of the raphia fibre revealed that the observed differences in the mean modulus were statistically significant in the treatment groups (F (4, 10) = [39.6], p<.001).

Table 1. Effects of the different treatments on the mechanical properties of raphia fibre

Sample	Tensile Strength (MPa)	Modulus (MPa)	Load at Break(N)
Untreated Fibres	50.0	24793.0	14.8
KOH	132.3482	1794.2186	12.5295
Hydrogen Peroxide	146.0181	5092.8589	13.8775
$KMnO_4$	133.7359	7006.8366	11.6679
Benzoyl Peroxide	40.9367	947.6872	25.5617

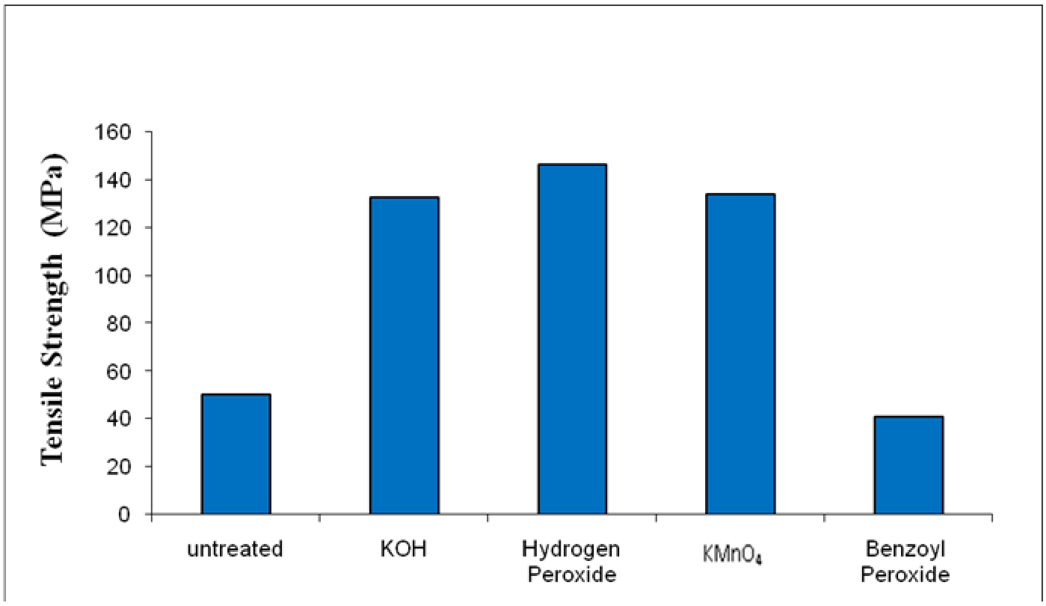

Fig. 1a. Effects of treatments on tensile strength of Raphia fibre

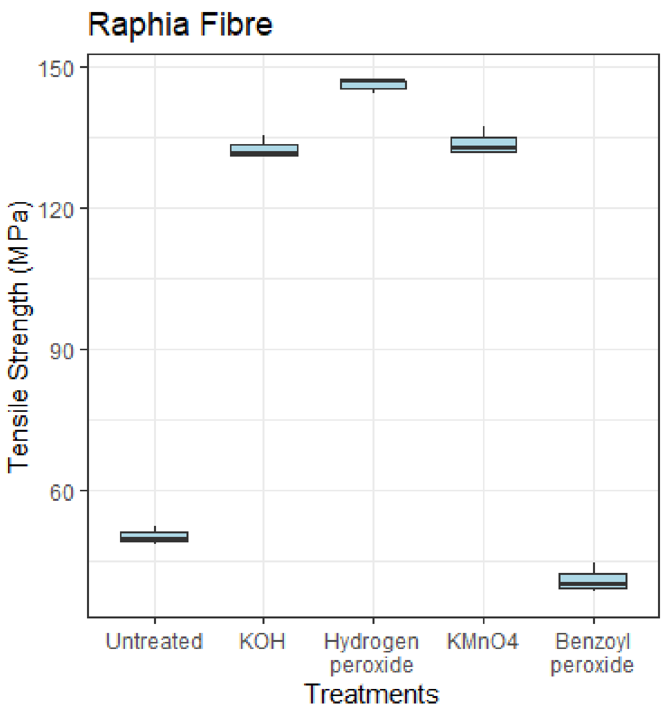

Fig. 1b. A one way ANOVA of the effects of treatments on the tensile strength of raphia fibre

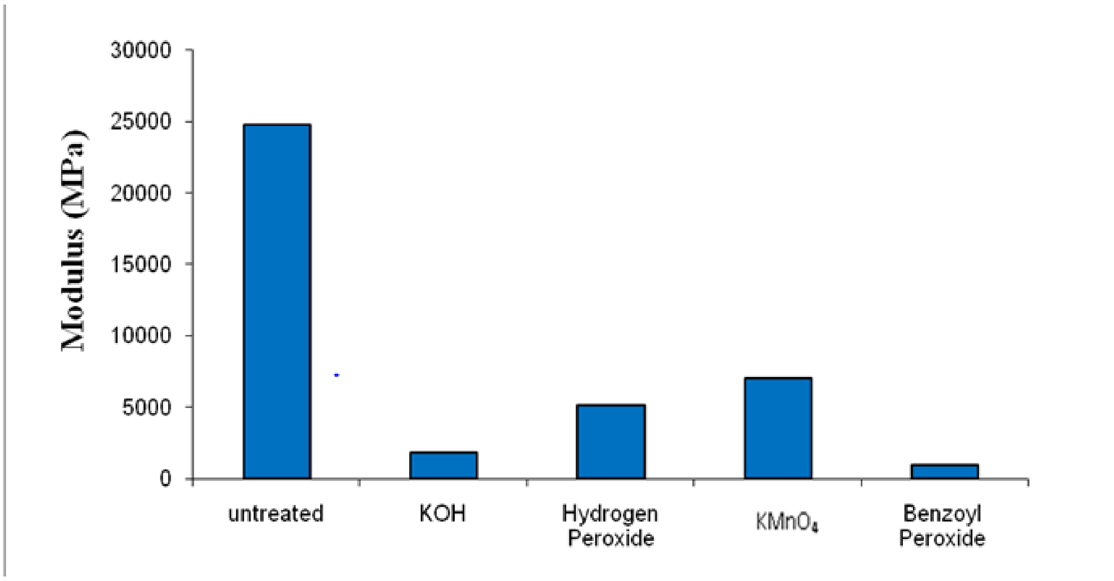

Fig. 2a. Effects of treatments on modulus of raphia fibre

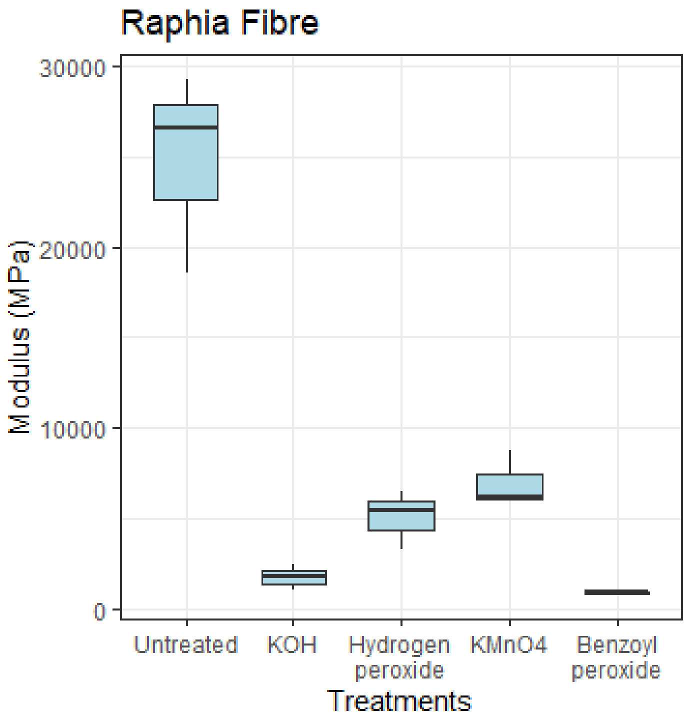

Fig. 2b. A one way ANOVA of the effects of treatments on the modulus

Table 2. Water absorption results of treated raphia fibre at various time

		1HR	3HR	6HR	12HR	24HR
Untreated Fibre	FB1	78.95	109.11	212.05	265.09	265.51
Benzoyl peroxide	FB2	21.92	100.69	209.92	245.57	245.97
Potassium hydroxide	FB3	61.74	101.74	217.39	271.67	271.03
$KMnO_4$	FB4	193.31	209.05	215.81	222.22	222.27
Hydrogen peroxide	FB5	114.29	209.01	238.89	328.57	328.57

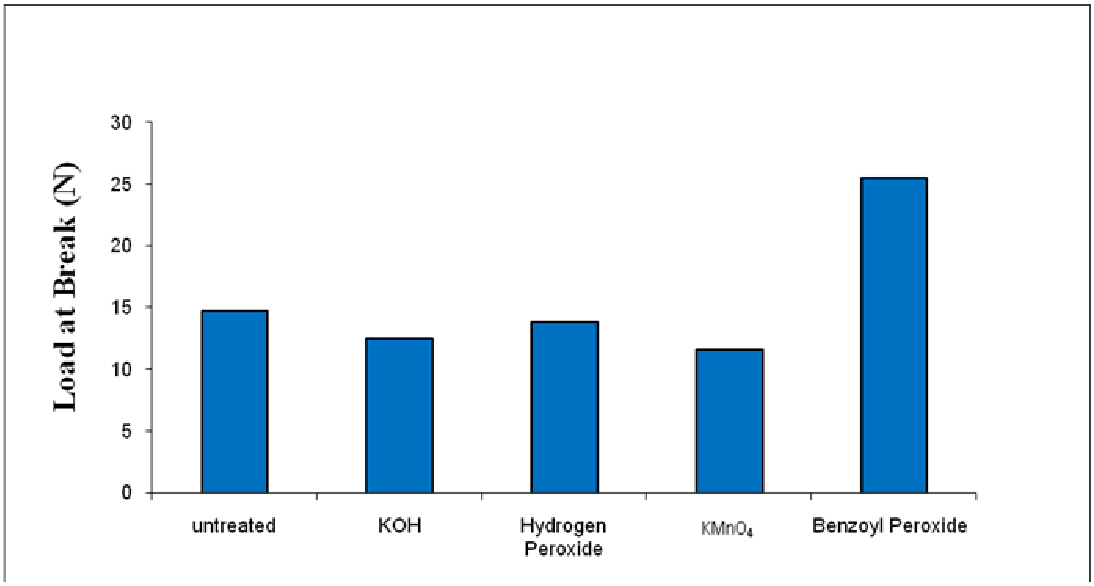

Fig. 3a. Effects of treatments on the load at break

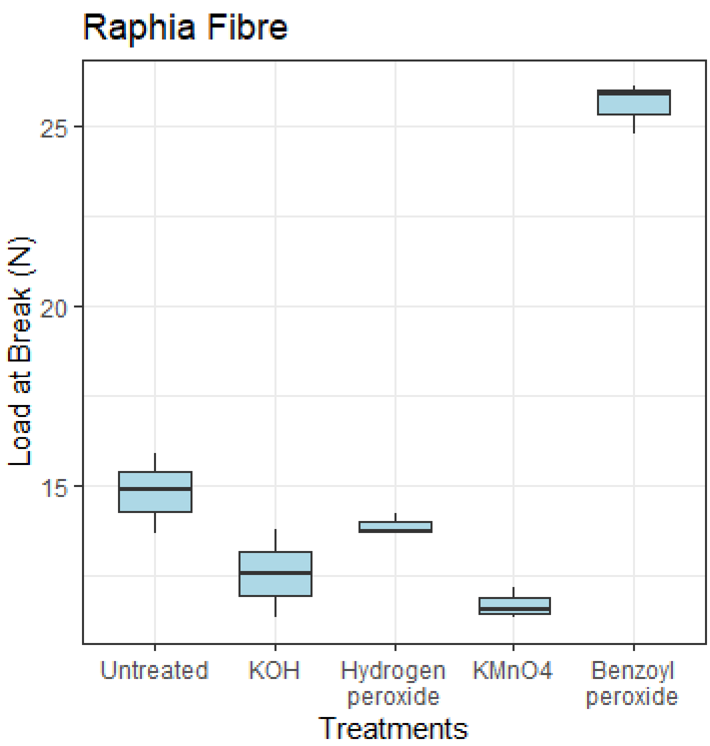

Fig. 3b. A one way ANOVA on the effects of treatments on the load at break

From Fig. 3, benzoyl peroxide treated raphia fibre showed superior load at break value (25.5617N), over untreated raphia fibre (14.7847N). $KMnO_4$ treated raphia fibre however showed the lowest value (11.6679N). The reduction in the value of the load at break maybe due to delignification and degradation of cellulosic chains during chemical treatment [15]. A one-way ANOVA that was performed to compare the effect of the different treatments on the load at break of the raphia fibres revealed that the observed differences in the mean load at break were statistically significant in the treatment groups (F (4, 10) = [136.75], *p*< .001).

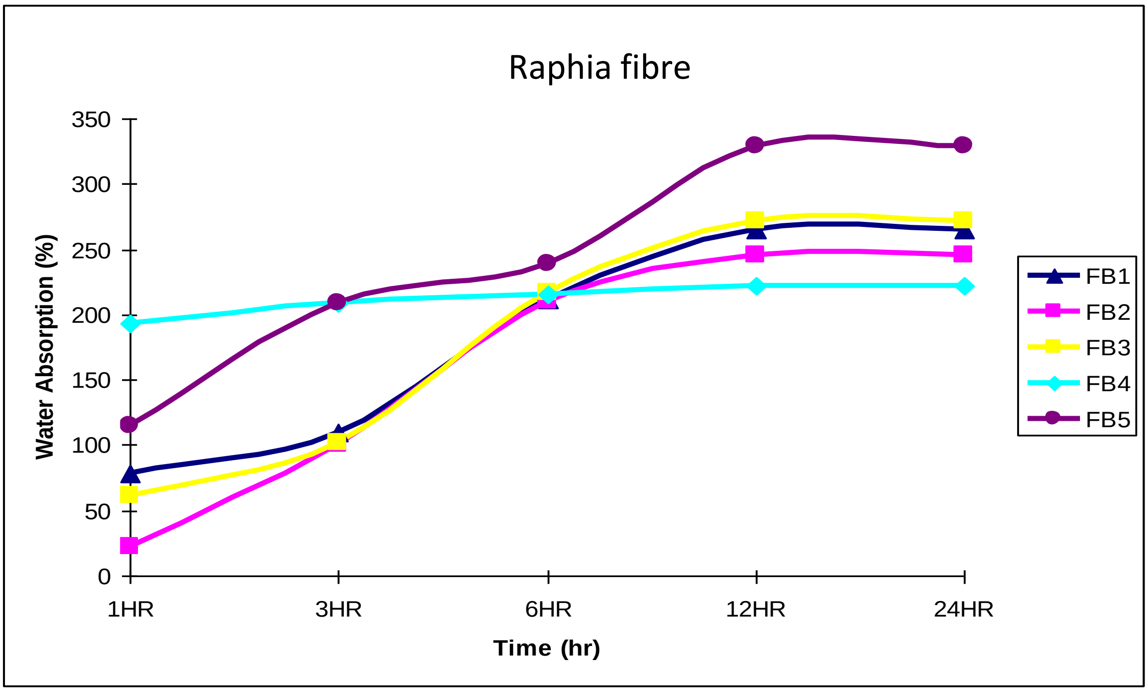

Fig. 4. water absorption of treated and untreated raphia fibre against time

Table 2, Fig. 4, showed water absorption for benzoyl peroxide treated fibre was lowest at 1hr, 3hrs 6hrs 12hrs & 24hrs, follow by potassium hydroxide treated fibre, hydrogen peroxide treated fibre have the highest absorption of water at the various time interval, while $KMnO_4$ treated fibres show little increase in absorption after 3hrs and shows the lowest absorption after 24hrs. It has been reported that chemical treatments remove hemicelluloses, lignin and amorphous region of cellulose, which are the main source of water intake, hence the reduction in the water absorption capacity of the fibre after treatment [16,17]. Sometimes, treatment intended to increase strength, can increase the surface area exposed to water or create new pores, enhancing water absorption of a fibre, hence the increase in water absorption after treatment. Furthermore, increase in water absorptiona maybe attributed to the increase in amorphous region (which is responsible for water intake) of the cellulosic fibre afty chemical treatment [18,19,20,21].

4. CONCLUSION AND RECOMMENDATION

The effects of potassium hydroxide, hydrogen peroxide, potassium permanganate and benzoyl peroxide on raphia fibre, have been studied. The properties of this fibre was improved by these chemical treatments

However base on this research, potassium hydroxide, hydrogen peroxide and potassium permanganate treatments are recommended for the fibre. From this study, benzoyl peroxide treatment has shown the highest reduction in water absorption capacity of the fibre, followed by potassium hydroxide treatment. They are therefore recommended for reducing the hydrophilic nature of the fibre

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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