Global Science Research Journals

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Research Article Open Access

Global Journal of Environmental Science and Technology

ISSN: Vol. 13 (1), pp. 1-6, March 2025

Alkali treatment on anatomical properties of Bhimal fiber

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Received: 12-Dec-2023, Manuscript No. GJEST-23-122567; **Editor assigned:** 15-Dec-2023, PreQC No. GJEST-23-122567 (PQ); **Reviewed:** 29-Dec-2023, QC No. GJEST-23-122567; **Revised:** 21-Mar-2025, Manuscript No. GJEST-23-122567 (R); **Published:** 28-Mar-2025, DOI: 10.15651/GJEST.25.13.016

ABSTRACT

Bhimal/*Grewia optiva*, natural fiber, being agricultural waste, possess various lucrative assets such as nontoxicity, eco-friendliness, capable of being burned, low in weight and cost. The fibers are eradicated from the branch and stem of *Grewia optiva* tree (*Grewia oppositifolia*). The treatment of Bhimal fibers is analysed in the article. Raw fibers are bleached and healed with sodium hydroxide (alkali treatment). Measurements of the diameter can be obtained through projection microscope and microtome. It was confirmed by an image taken with a microscope that the diameter of fiber had been decreased to about 54.72 micron. The impact of the alkali treatment technique on the surface of the fibre has been assessed in this paper. For the evaluation of fibre strength, bundle test have been done. Removal of cellulose enhances the interlocking capacity of fiber with the polymer and also reduces the water absorbing capacity. Although the bundle test has the benefits of being quicker, simple and more useful in practise, the single unit fibre test provides exact results.

Keywords: *Grewia Optiva*, Bhimal, Mercerization, Bundle strength, Fiber fineness

INTRODUCTION

Natural fibers are lucrative in the technical field due to their low cost, biodegradability, easily extracted, processed and help in decreasing the use of fossil resources (Ramamoorthy et al., 2015; Mohammed et al., 2015). The sky touching cost of fossil fuels boosts the rate of interest in biodegradable resources. Bio-composites that effectively use natural fibers (bio) have favourable environmental effects (Chauhan and Chauhan, 2013). The benefits of using cellulosic bio fibers over traditional synthetic reinforcements manufactured by humans, such as glass, include biodegradability, low concentration and price, reduced wear, high toughness and non-corrosiveness (Begum et al., 2020).

The researchers were driven effectively to utilize agricultural waste by the potential performance of cellulose microfibers and the rising concern for environmental protection. New lightweight composite materials are being processed more regularly since they are inexpensive and renewable. One of the fibrous plants that may be found in India's Himalayan mountain ranges is *Grewia optiva*. It is a little plant that can reach heights of 9 to 12 meters and mostly it is found between the farming fields as agricultural waste. To extract cellulose from natural fibers, researchers employ several techniques such as chemical treatments, electro spinning and steam explosion. The conventional chemical process for removing microfibers from plant fibers and agricultural waste is a steam explosion. The mechanical interlocking of the resin is enhanced by chemical procedures.

Singha et al. stated that particle-reinforced composite is the strongest among short, long and particle fiber. Singha et al. also concluded that benzoylated fiber shows enhanced water absorption and alkaline/mercerized represents increased water retention with UPE polymer. Bajpai et al. observed that by including bio fiber, the characteristics of the composite have enhanced.

In this study, raw fiber was processed into alkaline *Grewia optiva* through surface functionalization.

MATERIALS AND METHODS

Materials

Bhimal have a great future as a reinforcement agent in composites (Hearle, 1963) among the various kinds of natural fibrous materials. It is found in Uttarakhand and crucial species for a land management strategy as seen in Figure 1. Karakoti et al. concluded that micro cellulose fiber was extracted by chemo-mechanical method. It is procured from Uttarakhand bamboo and fiber development board. Bhimal offers wood for fuel, fiber, and leaf food. As depicted in Figure 2, hackling cleans and straightens the fibers. Alkali treatment (NaOH) and bleaching are used to mercerize raw fiber (Singh et al., 2013; Rana and Singha, 2014). It will disrupt the hydrogen bond in molecular structure and strengthen the interlocking between the composite's fiber and polymer (Sett et al., 2016; Setswalo et al., 2023) as shown in Equation 1. The waxy substance from the outer lining of fiber is also removed during this process (Kaur et al., 2023).

Bio fiber –OH+NaOH → Bio fiber– $O\text{-}Na^{+}+H_2O$+Surface impurities (1)

Figure 1 (a-d): Extraction of fiber from the shoot of Bhimal.

Extraction of Fiber

Shoot of *Grewia optiva* tree is soaked in running water. These are dried and fibers are peeled off. Raw fiber is procured from the processing of outer stem layers of the Bhimal plant. It has been procured from the processing of the outer stem layers of the Bhimal plant. It has been purchased from Uttarakhand bamboo and fiber development board, Dehradun. The utilization of *Grewia optiva* in various articles and composites also reduces agricultural waste (Musio et al., 2018).

Figure 2 (a) shows the processing steps for the extraction of *Grewia optiva*. Lignin, cellulose, and hemicellulose make up natural fiber. The use of raw fibers without any treatment is not appropriate for the mechanical characteristics of composites. The samples of composite made by these will end in high water absorption.

Figure 2: Processing of fiber (a) Extracted fiber and (b) Hackled fiber.

Surface Treatment of *Grewia optiva*

There are several surface treatment techniques available for fibers namely mercerization (alkali treatment) (NaOH), delignification, benzoylation (C_6H_5CO), silanization (R′ $(CH_2)_nSi(OR)_3$) and graft copolymerization (branch copolymer) (Singha and Rana 2012). In this study, simple laboratory techniques were used to convert raw fiber into Cellulose $(C_6H_{10}O_5)_n$ micro *Grewia optiva* (Kakkeri, 2021). Singha et al. confirmed the surface modification of bio fiber by FTIR and SEM. He also stated that hydrophobic characteristic of *Grewia optiva* is enhanced after functionalization.

In this article, mercerization technique is used which is an alkali treatment. *Grewia optiva* obtained were cut into 40 mm approximately. This method is sufficient for creating a hydrophobic layer on them as shown in Figure 3. It provides better interfacial characteristics between fiber and matrix (Kumar et al., 2017). It also enhances the thermal and inherent strength of the reinforced structures. Figure 1 shows the preparation process for isolating cellulose micro *Grewia optiva*. Its shoot that was 1.5 to 2.5 meters in length were chopped into roughly 40 mm pieces (Jiang et al., 2017). Raw fibers were autoclaved at 120°C and 137 kPa pressure while being soaked in 10% NaOH. Proper care must be taken as sodium hydroxide is difficult to remove, so the fibers underwent washing and hot air oven drying (Kumar et al., 2019).

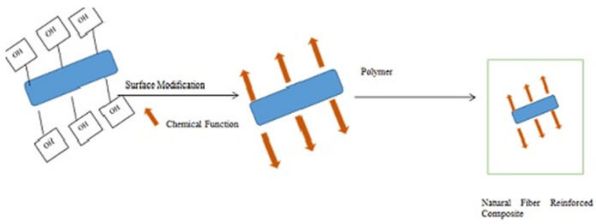


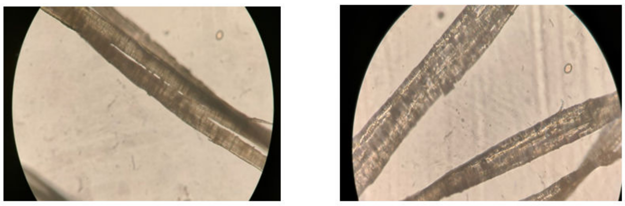
Figure 3: Schematic representation of surface treatment.

Singha et al. concluded that treated *Grewia optiva* shows more resistance toward water absorption. Setswalo et al. said that the elimination of hydrophilic components enhances the water resistance of composite.

Structure of Fiber

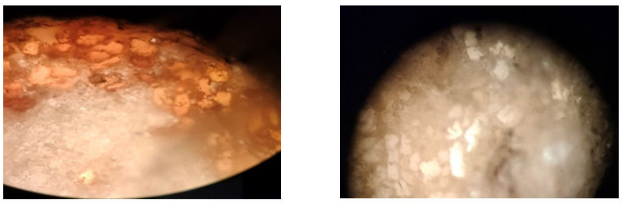
Grewia optiva is in the category of bast fiber. The main ingredients that affect their properties are cellulose, hemicellulose, lignin, waxes, oils, and pectin. Cellulose of three elements such as carbon, hydrogen, and oxygen. Cellulose is in the form of tiny fibers within the cell wall of a plant. The tensile strength of natural fiber is simulated by the content of consists cellulose which decreases with the increasing age of the plant. In addition to some ash components, lignin frequently contains a variety of carbohydrates, lipids and protein compounds. Hearle et al. observed that fibrillar structure gives a better explanation of most of fibers. Kumar et al. concluded that the hydrophilic nature of fibers and the hydrophobic nature of matrix is the main drawback of their interaction. He also mentioned various surface functionalization techniques to enhance interfacial properties.

Light microscopy, laser diffraction and Scanning Electron Microscopy (SEM) are the three methods most frequently used for measuring diameter and the technique used to examine is microscopy. The longitudinal section as shown in Figure 4(a) and 4(b) represent the removal of Cellulose $(C_6H_{10}O_5)_n$. As shown in Figure 5, the difference between the cross-sectional image of raw and treated fiber.



(a) (b)

Figure 4: Microscopic image of *Grewia optiva* fiber of longitudinal section (a) Raw fiber (b) 10% Mercerized fiber.



(a) (b)

Figure 5: Microscopic image of *Grewia optiva* fiber of cross sectional view (a) Raw fiber (b) 10% Mercerized fiber.

Hackling of Fiber

Hackling is one of the last three steps for the fiber to be spun into yarn (Gupta and Chauhan, 2022). This process is adequate for bast fibers as shown in Figure 6. It removes the impurities and straightens, leaving them clean and dry, as seen in Figure 2(b). These had inadequate denier (fineness), mercerization optimises the denier or fineness. The optimum value of denier means better cohesion between the surfaces of individual fibers in a bundle.

Figure 6: Hackling of fibers.

RESULTS AND DISCUSSION

Diameter of Fiber

Raw fiber (untreated) is 75.72 microns in diameter while that of treated is 54.72 microns in diameter. Mercerization is a technique for surface modification or functionalization (Liu et al., 2011). The shape of cross section of varies from oval to circular. This technique involves applying NaOH to the fiber (sodium hydroxide). Here 10% of NaOH solution is used. Raw fiber has a higher hemicellulose, lignin and lower cellulose content before chemical processing. Hemicellulose and lignin levels are further decreased by the alkali treatment. The continuous treatment makes it easier for microfibril to separate from the cell wall.

Bundle Strength

Every chemical process increases cellulose content. As the hydrophilic aspect reduces the strength and improves the ability of alkali-treated *Grewia optiva* fibers to act as reinforcement (Jiang et al., 2015). As shown in Figure 7, the strength of raw and treated fibers is measured using a stelometer, here these are taken in bulk. The optimum number of fibers in bulk is 30 and 100 respectively. Before treatment, the strength is 24.45 g/tex.

As can be seen in Table 1, the alteration of the fiber decreases the bundle strength by decreasing the ability of cellulose to bind hydrogen, which in turn prevents hydroxyl groups from interacting with water molecules as shown in Equation 1. As these are taken in a bundle, its strength is termed as bundle strength (Bello and Cecchi, 2017). After mercerization its strength reduces to 15.57 g/tex.

(a) (b)

Figure 7: Measurement of bundle strength, stelometer (a) and (b).

Fiber Fineness

Fiber fineness is very poor, 160.52 denier as shown in Table 1. The quality of the surface enhances after its functionalization (Balakrishnan et al., 2019; Hosseinkhani et al., 2012). The fineness reduces to 125.62 denier which means 125.62 gram of fiber in 9000 meters of length (Singha and Thakur, 2009). It represents the smoothness and bending capability of fiber. It is calculated using the cut weigh method. The specimens were varnished with a thin layer of gold using a sputter coater before inspection (Jeol JSM 5310). A beam current of 34 mA and an accelerating voltage of 10 kV was used to set up the observation in the secondary electron mode.

Table 1: Properties of fiber.

S. no	Fiber	Diameter (micron)	Area (m^2)	Bundle strength (g/tex)	Fiber fineness (Denier)
1	Raw fiber	75.72	4503.094×10^{-12}	24.45	160.52
2	Mercerized fiber	54.72	$2351.7007 \times 10^{-12}$	15.57	125.62

Area of Fiber

When examined under a microscope as depicted in Figure 8, each bio fiber exhibits a unique cross sectional look. The shapes range from rounded to oval and each shape influences particular aspects of the textile or woven mat. Although most synthetic have a circular cross section throughout the production process, the form may be changed or manipulated for the natural fibers. As depicted in Table 1, before condition is 4503.094×10^{-12} m^2 and after the treatment is $2351.7007 \times 10^{-12}$ m^2. The area (Sc) is calculated from the diameter (dn where n=1, 2, 3, 4, 5) of the fibers which have been recorded from the optical microscope.

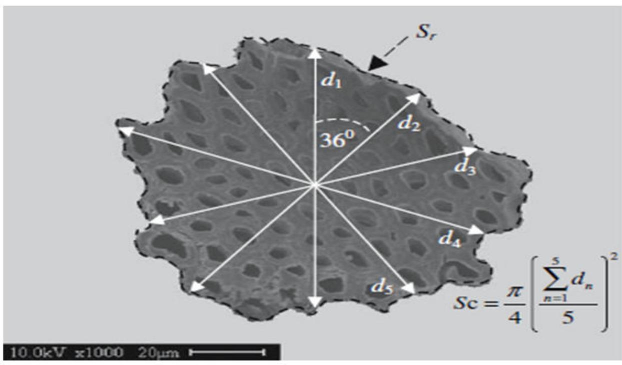


Figure 8: Calculation of area of cross section of fiber from the average of five diameters.

Swelling of Fiber

Dry bundle of raw and mercerized bundle of fibers were soaked in water for 3 hours. This set up was done to test the difference between the swelling behaviour of treated and non-treated bundle of fibers. These are not wipe with tissue to remove extra moisture (Table 2).

Table 2: Weight of bundle of treated and non-treated fibers.

S. no	Bundle of fibers	Weight of dry fibers (gm)	Weight of fibers soaked in water (gm)	%W moisture absorption
1	Raw	0.0516	0.225	336.05%
2	Mercerized fiber	0.0643	0.1562	58.83%

As can be seen in Table 2, weight of fibers increases after being soaked in water. This shows that these are having affinity towards moisture, so swelling of them occurs.

%W=(Wf-Wi)/Wi (1)

Percentage of swelling and moisture absorbance can be calculated using above Equation (1). Raw fibers absorb more moisture, 336.0465% in comparison to surface treated mercerized one which is 58.83%. It occurs due to presence of hydroxyl group in the structure of bio fiber. Mercerization removes hydroxyl group and introduces chemical function. It also improves interlocking between fiber and polymer.

CONCLUSION

Considering the results, *Grewia optiva* (GO) fibers are successfully extracted and finally converted into woven mat. Complete procedure is environment friendly, of low cost and efficient. The cross-sectional shape of fiber varied widely from noncircular shapes such as a kidney bean shape to circular. It has also been noticed that under ambient room conditions, there are no changes in the conditions of fiber. The surface of the fiber was modified to improve its interacting capacity with the polymer. Alkali treatment increases the interlocking capacity of fiber. Enhancement in hydrophobic character and chemical resistance behavior of surface modified *Grewia optiva* fiber has also been observed by the measurement of weight of fiber bundles. Ordinarily, fibers are bundles and the size of a bundle depends mainly on number of single entity in a bundle. The cross-sectional shapes of single fiber provided were polygonal to round. Its denier is poor even after functionalization. Its spinning into yarn was difficult, though forming its woven mat for structural composite is epitome for society due to its strength and environmental concern.

CONFLICT OF INTEREST

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

AUTHOR’S CONTRIBUTION

Both the authors contribute equivalently in the research article.

FUNDING

The research work was self-funded. No funding was available at any stages of the research.

AVAILABILITY OF DATA AND MATERIALS

All data generated or analyzed during this study are included in the article.

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