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Effect of carding process and mercerization on the mechanical properties of *Grewia optiva* bast fiber

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Abstract
The applications of biocomposites are increasing to achieve sustainability in many applications. Biocomposites are formed by reinforcing natural fibers in different forms in the bioresin. Non-woven form of fibers is becoming popular to fabricate biocomposites because of being cost-effective and quick in manufacture. The process of carding is involved in both woven and non-woven fabrics which affect the mechanical properties of the fibers. The tensile properties of *Grewia optiva* natural fiber have been studied before and after carding and have been discussed in this paper. It has been found that the carding of fibers is increasing the brittleness of the fiber and the tensile strength is decreasing by 29.21%. The work to rupture of the fibers after carding is decreasing by 48.9%. Similarly the percentage elongation and denier of carded fibers are 21.94% and 21% lesser than the non-carded fibers. Hence, it has been concluded that the carding process should be optimized to minimize the effect on the mechanical properties of fibers.

Keywords: Carding, biocomposite, mechanical properties, mercerization

Introduction

Uttarakhand is very affluent in biodiversity and the people here are dependent on various forest resources for their livelihood [1]. Natural fibers obtained from trees are one of such resources which are abundantly available in Himalayan terrain. *Grewia optiva* is a medium sized tree copiously found in Uttarakhand and is a good source of bast fibers [2]. These natural fibers are used by the local people for various applications like ropes, baskets, crafts, etc. [3]. The natural fibers obtained from different parts of plants and crop wastes are eco-friendly and cheap, hence gaining popularity in national and international markets [4]. In the recent decades, natural fibers have allured the researchers for the production of natural fiber reinforced composites [5-10] which have a potential to replace many non-biodegradable materials in various applications depending upon their mechanical properties. The use of natural fibers for different applications can be a sustainable way to achieve stability of the ecosystem. There are many research papers available on natural fibers reinforced composites like hemp [5], sisal [7], bamboo [9] etc. but the study on *Grewia optiva* fiber is rarely available [11-13]. Since the mechanical properties of the composite material directly depends on the mechanical properties of their constituent materials, therefore it is very important to study the properties of the reinforcing material. For the fabrication of biocomposites the natural fibers are used as the reinforcement in different forms like woven and non-woven. Non-woven form of fibers is becoming popular to fabricate biocomposites because of being cost-effective and quick in manufacture. The process of carding is involved in both woven and non-woven fabrics which affect the mechanical properties of the fibers. The effect of the carding process on the mechanical properties of *Grewia optiva* natural fiber have been studied and discussed in this paper.

Material and Methods

The present study has been carried out on the *Grewia optiva* fiber obtained from Okhalkanda block of Nainital district, Uttarakhand. The fiber was extracted from the tree using a water retting process. The fiber as obtained from the water retting and sun drying has been designated as un-carded fiber. Then the fiber was cut in 8-10 cm length to make it suitable for the carding process.

Fig 1: (a) Un-carded fiber, (b) Carded Fiber

Fig 2: Automatic Single-Fibre Tester FAVIGRAPH

Carding of *Grewia optiva* Fibers

Then the carding process was carried out on the fiber. The carding of fiber was facilitated by Obeetee Textiles Pvt. Ltd., Rudrapur, Uttarakhand. Carding is a process which separates and disentangles the individual fibers, removes most of the short damaged fibers and impurities, and makes the fibers lie parallel. After the carding process the fibers are spun in the form of a yarn to make woven fabric or carded fiber is directly transformed to a non-woven fabric. This process of carding may change the mechanical properties of the fiber because it involves the process like needling and combing. Hence the change in the properties of un-carded (figure 1(a)) and carded fibers (figure 1(b)) have been studied. The fibers are also treated by NaOH for improving the bonding with matrix material [14]. Hence a study on the change in the properties of fibers after 5% NaOH treatment has also been done.

Mechanical Testing: The mechanical and physical properties of *Grewia optiva* fiber have been tested in an automatic Single-Fibre Tester FAVIGRAPH (shown in fig 2) at Pasupati Acrylon ltd., Kashipur, Uttarakhand. The properties of the fibers tested are; Tensile Strength, Elongation, Work to rupture and Denier.

Results and Discussion

Tensile Strength: Tensile strength or breaking strength of a fiber is the force required to break the fiber per unit cross-sectional area. The textile unit for the measurement of tensile strength of fiber is gf/tex. Figure 3(a) represents the variation in the tensile strength from non-carded to carded fibers and the effect of NaOH treatment on the tensile properties of fiber. The average tensile strength of the non-carded fibers is 181.778 gf/tex while their tensile strength decreased to 176.245 gf/tex due to the carding process. The NaOH treatment of fibers also influenced the strength of fibers in negative aspects. A decrement of 3.04% is seen in the non-carded fibers while a decrement of 4.7% in carded fibers. Since the treatment of fibers with NaOH improves their bonding with the matrix material, therefore the decrease in the strength of fibers may be compensated by a better wettability of reinforced fibers.

Elongation: The effect of carding and NaOH treatment is depicted in figure 3(b). Both carding and NaOH treatment makes the fiber more brittle. Elongation of the fiber is given in terms of percentage change in the length of fiber. The percentage elongation for the non-carded fiber is obtained as 3.3% only while it further decreased to 2.57% after carding. After NaOH treatment, the non-carded fiber gives 3.08% of elongation while carded gives only 2.31% of elongation.

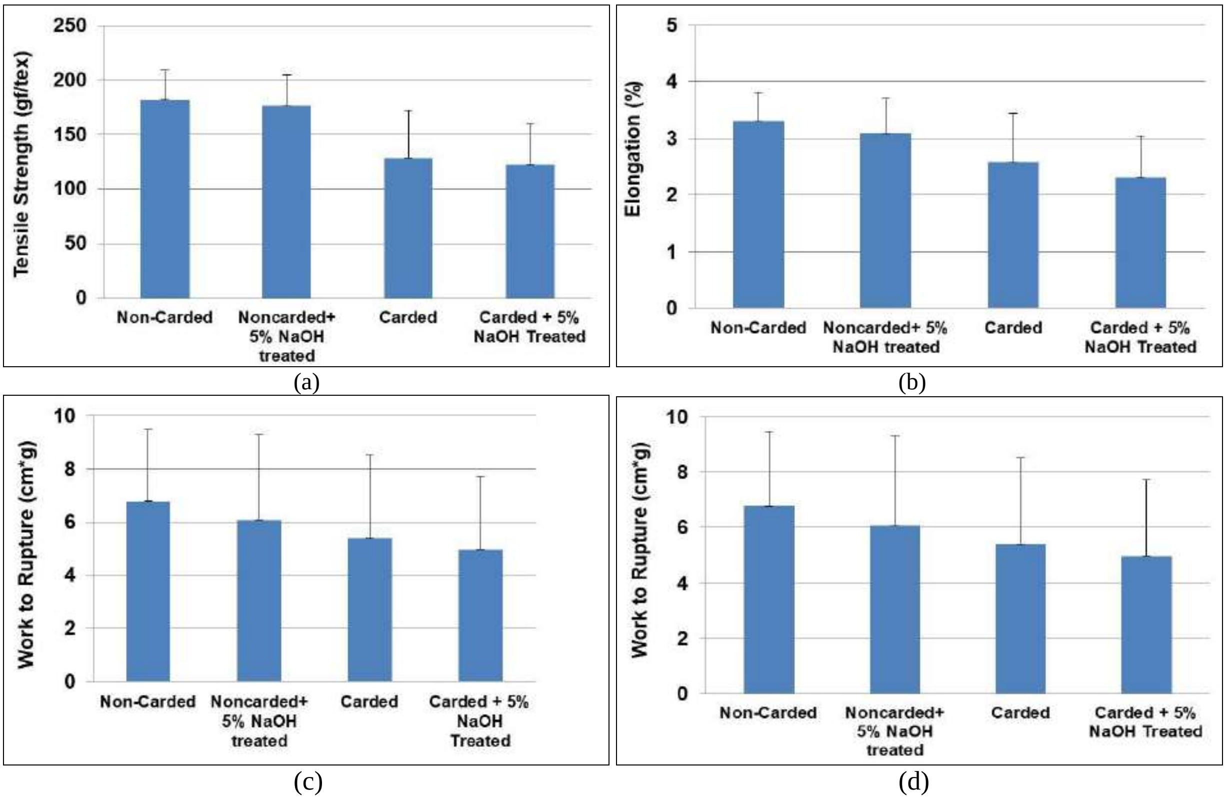

Fig 3: Mechanical and Physical properties of *Grewia optiva* fiber

Work to Rupture

Work to rupture is the property of a fiber which indicates the amount of energy a fiber can store before failure. The figure 3(c) shows the variation in the amount of work to rupture after carding and NaOH treatment. It can be clearly observed that carding and NaOH treatment both decrease the capability of fiber to store energy before failure. Its value for the non-carded fiber is 6.78 g.cm and for carded fiber is 5.39 g.cm. After NaOH treatment their respective values are 6.08 g.cm and 4.96 g.cm.

Denier

Denier for a fiber is its linear density which indicates the thickness of the individual fiber threads. A fiber with high denier count is thicker than fiber with lower denier count. The figure 3 (d) indicates that the fiber becomes thinner after the carding process which is responsible for decreasing all the mechanical properties of the fiber. Similarly NaOH treatment also reduces the denier of the fiber. The average thickness of the non-carded fiber is measured as 21.31 denier and a further treatment with NaOH reduces it to 15.98 denier. The denier count for carded fiber is found as 10.596 and NaOH treatment further reduces it to 9.07.

Conclusion

The following conclusions have been drawn by the study done on the carded and NaOH treated fibers:

1. The carding process on the fiber reduces its denier count which indicates that the fiber becomes thinner after carding. Similarly the denier is also reduced after NaOH treatment.
2. Due to the reduction in the denier count of the fiber all the mechanical properties like tensile strength, percentage elongation and work to rupture also decreases, when the fiber undergoes carding and NaOH treatment.

Hence, it is important to optimize the carding process, so that the strength is not reduced much while converting the raw fiber into woven and non-woven fabrics which can further be used for reinforcement in biocomposites. Similarly, it is also necessary to optimize the amount of NaOH solution for the treatment of fiber, so as to obtain better wettability without reducing the final strength and other mechanical properties of the biocomposites.

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