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CONFERENCE PAPER

THE IMPACT OF DIVERSE CHEMICAL MODIFICATIONS ON THE PROPERTIES OF CALOTROPIS GIGANTEA BAST FIBER

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Abstract

This study examines the chemical surface modification of *Calotropis gigantea* (CG) bast fiber to enhance its performance as a reinforcement material in polymer composites. Fibers were treated with sodium hydroxide, potassium permanganate, sodium chlorite, and benzoyl chloride and their effects on physical, mechanical, thermal, and morphological properties were evaluated. Characterization techniques included density measurement, tensile testing, thermogravimetric analysis (TGA), Fourier transform infrared spectroscopy (FTIR), and surface morphology analysis. The alkali-treated CG fiber exhibited superior performance, with a tensile strength of 210.39 MPa and a Young's modulus of 1.77 GPa. Furthermore, the crystallinity index increased by 25.37% compared to untreated fibers. The results indicate that chemical treatment, particularly alkali treatment, significantly enhances interfacial and structural properties of CG fibers. These improvements demonstrate the potential of chemically modified CG bast fiber as a sustainable and efficient reinforcement for polymer composite applications.

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Introduction:-

Environmental awareness in the current global scenario paved the way for researchers and academics to explore natural fibers and their composites. The use of synthetic materials such as Kevlar, nylon, glass fibers, aramid, etc., leads to serious environmental hazards during dispose. It is a no biodegradable material causing landfills and affecting water and air (Thakur, Thakur, and Gupta 2014). Therefore, the growing environmental awareness throughout the world has triggered a paradigm shift toward the use of natural fibers as an attractive alternative to synthetic fibers. It provides positive environmental benefits with respect to ultimate disposability and raw material utilization (Nayak and Mohanty 2018b).

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But the major problem relating to the use of natural fibers in fiber reinforced polymer (FRP) composites is their moisture-absorption property. To overcome the above problems, natural fibers (NFs) are often chemically treated to modify the surface properties (El-Shekeil et al. 2012; Nayak and Mohanty 2018a). The chemically treated fiber possesses better interfacial properties compared with untreated fiber and by which better bonding of polymer is also achieved. At present, from the literature available it can be seen that the fibers extracted from CG stem bast were characterized without any chemical modifications (Ganeshan et al. 2018) or only alkali treated CG fibers were characterized and compared with untreated CG fibers (Ramasamy, Obi Reddy, and Varada Rajulu 2018). So, this research aims to give various chemical treatments (like sodium hydroxide, potassium permanganate, sodium chlorite and benzyl chloride) to modify the surface of this CG bast fiber and explore their effects on mechanical, thermal, and water absorption properties along with other characterizations such as Fourier transform infrared spectroscopy (FTIR), XRD, and thermo-gravimetry analysis (TGA). It is expected that this study may pave the way for developing polymer matrix composites by reinforcing this novel fiber in the near future.

Materials and Methods:-

Material preparation:-

Calotropis gigantea plants (Figure 1a) were obtained from adjacent local areas in Khurda, Odisha, India, between November and December. The plant yielded 30 cm-long stems (Figure 1c). They were completely cleansed with fresh water and sun-dried for 2-3 days. Figure 1d shows the removal of the bast from the stem. After soaking in water for 10-15 days, bast fibers were removed using the retting technique. The isolated fibers were oven-dried at 70°C for 24 hours to eliminate any moisture present. The fibers at this stage were designated as untreated (raw) CG fibers (Figure 1e). Chemicals such as sodium hydroxide, potassium permanganate, sodium chlorite, and benzoyl chloride of analytical grade were employed without any further purification. All solutions were produced in double distilled water.



Figure 1. *Calotropis gigantea* (a) plant (b) stem (c) extracted stem (d) extracted bast from stem (e) extracted fibers.

Results:-

Tensile properties:-

The single-fiber tensile tests were performed to explore the mechanical properties of the untreated and various chemically treated CG fibers. The mechanical properties of the fibers such as tensile strength, young's modulus and elongation at break % are presented in figure 2. From the figure, it is observed that the tensile strength of all the treated fibers is found to increase in comparison to the untreated one. From Figure 2a, it is found that the tensile strength of CG fibers changed drastically after chemical treatment. This is expected and in general agreement with the literature (Vijay et al. 2019). The CG fibers treated with NaOH (alkali treatment) reveals highest tensile strength of 210.39 MPa, which is 35.73%, 21.54%, 29.48% and 16.21% higher than the untreated, permanganate, sodium chlorite and benzoylation CG fibers. This could be due to the elimination of micro cracks and voids present on the fiber surface after the treatment as evident from SEM images. The young's modulus (Figure 2b) is higher for the treated fibers when compared to the untreated fibers.

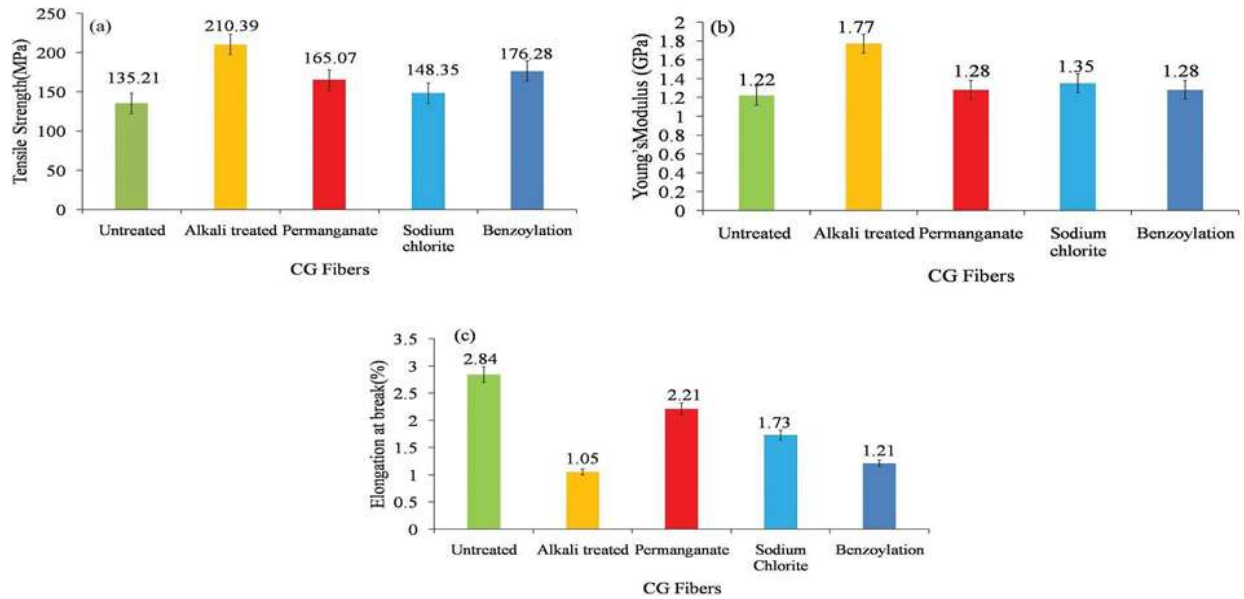
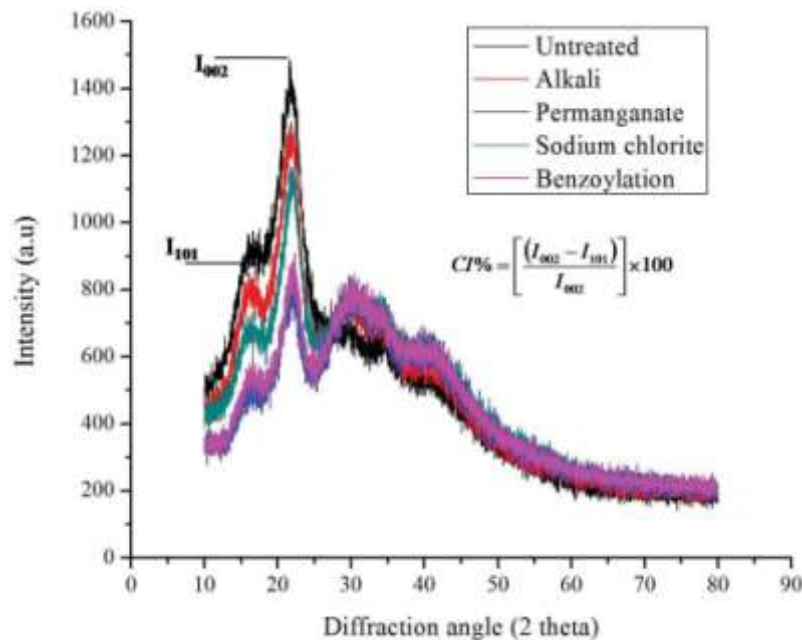


Figure2. Mechanical properties of CG fibers.

X-Ray diffraction (XRD):-

The X-ray diffractograms of untreated and chemically treated *Calotropis gigantea* (CG) fibers (Figure 3) exhibit two prominent peaks at $2\theta \approx 18^\circ$ and 23° , corresponding to the (101) and (002) planes of cellulose I, respectively. The results indicate that no phase transformation from cellulose I to cellulose II occurred after chemical treatment. The crystallinity index (CI) values increased for all treated fibers, with alkali-treated fibers showing the highest improvement (~20.23%). This enhancement is attributed to the removal of amorphous components such as lignin and hemicellulose, which promotes a more ordered and crystalline cellulose structure.



I.

Figure 3. XRD of untreated and treated CG fibers.

TGA analysis:-

Thermal degradation behavior of untreated and chemically treated *Calotropis gigantea* (CG) fibers is shown in Figure 4. All fibers exhibit three-stage degradation, with treated fibers demonstrating improved thermal stability compared to untreated fibers.

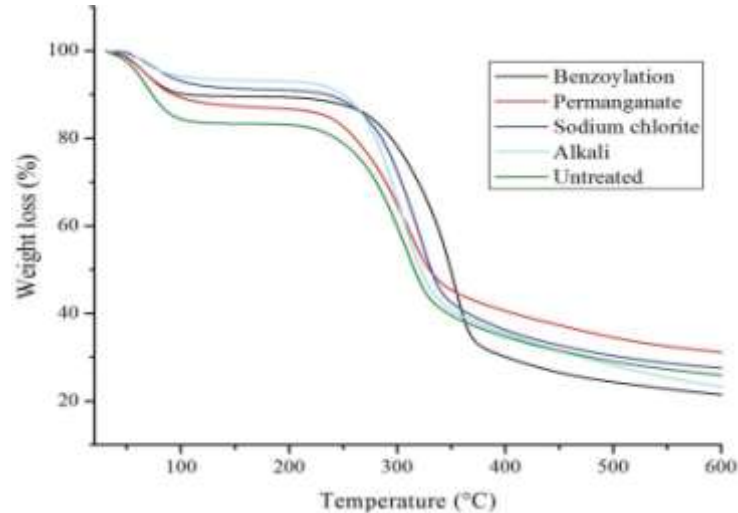


Figure 4. TGA of untreated and treated CG fibers.

Morphological analysis:-

The surface texture of untreated and various treated CG fibers are shown in 5. The SEM of untreated CG fiber is shown in Figure 5a. From SEM image it can be seen that the raw CG fiber was covered with fatty and waxy substances for which surfaces is seen smooth and shiny. It is well known that the fiber

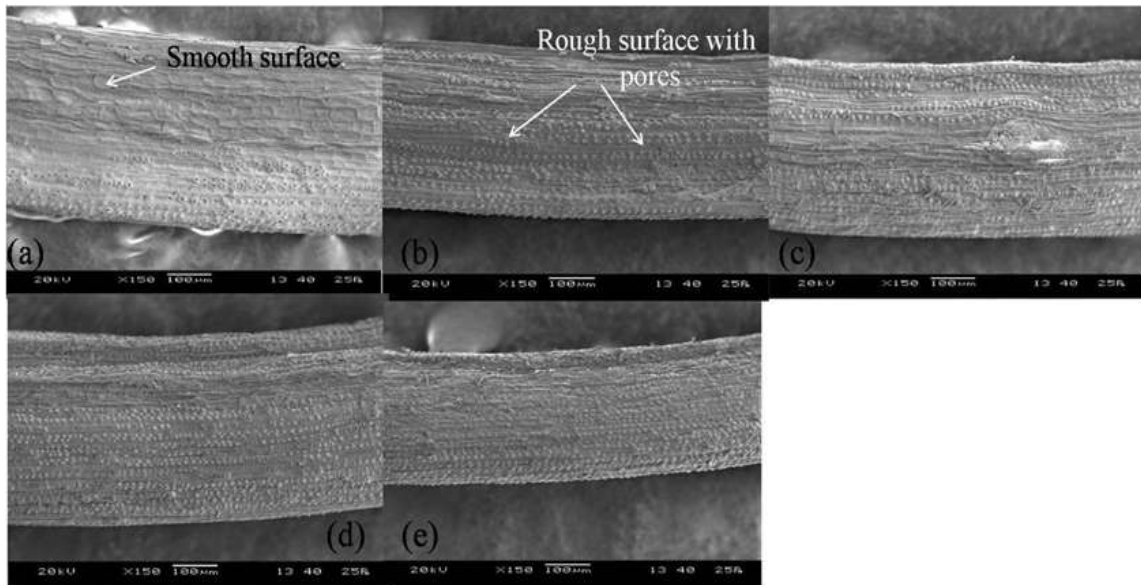


Figure 5. SEM image of (a) untreated (b) alkali treated (c) benzoylation (d) sodium chlorite (e) Permanganate CG fibers.

Characterization results were affected by the impurities existing on the fiber surface. On the other hand, rough surface is observed from the surface of treated fibers (Figure 5b–e) due to the elimination of impurities and a major part of hemicellulose and lignin which provides good adhesion at the fiber/matrix interface in composites. In the case of alkali-treated CG fibers (Figure 5b), it is clearly seen that micro-pores is developed with many pits and holes on fiber surface. This

is may be due to the removal of lignin, waxy epidermal tissue, adhesive pectin, and hemicelluloses which makes the surface rough thereby causing fibrillation. Further removal of fatty deposits occurs in other treated fibers (Figure 5c–e).

Conclusions:-

The effects of chemical alteration on the physical, mechanical, thermal, and morphological properties of cellulose fiber isolated from *Calotropis gigantea* bast were investigated and discussed. After treatment, the cellulose content of the fiber rose, but the other chemical constituents tested showed the reverse tendency. The density of CG fibers increased following chemical treatment. Alkali-treated fibers were shown to have higher strength than other chemical treatments. The tensile strength of alkali-treated fiber was found to be 210.39MPa, 35.73% higher than that of untreated CG fiber. The treated fibers outperform untreated fibers in terms of thermal deterioration at elevated temperatures, with alkali-treated fibers losing less weight overall. The FTIR spectra also confirmed that the fiber's amorphous constituents were condensed after treatment. Overall, the study concludes that alkali-treated *Calotropis gigantea* fiber is a suitable reinforcement material for polymer matrix composites intended for light load-bearing applications. Based on the positive and encouraging results, the research can be expanded to create alkali-treated *Calotropis gigantea* fiber-reinforced polymer composites and evaluate their static and dynamic mechanical properties.

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