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## Harnessing the Potential of 'Okra Bast Fiber' for Technical Textile Applications

**Kshetrimayum Dolly Devi<sup>1</sup>, Surabhi Mahajan<sup>2</sup>,  
Ammayappan Lakshmanan<sup>3</sup> & Kartick  
Kumar Samanta<sup>4</sup>**

<sup>1</sup>Ph.D. Scholar (Corresponding Author), Punjab Agricultural University,  
Ludhiana-141004, Punjab (India) E-mail:<dollykshetriya@outlook.com>

<sup>2</sup>Associate Professor, Punjab Agricultural University,  
Ludhiana-141004, Punjab (India)

<sup>3</sup>Principal Scientist, ICAR- National Institute of Natural Fibre Engineering  
and Technology, Kolkata-700040, West Bengal (India)

<sup>4</sup>Senior Scientist, ICAR- National Institute of Natural Fibre Engineering and  
Technology, Kolkata-700040, West Bengal (India)

### Abstract

*Okra (Abelmoschus esculentus) is an important agricultural crop whose stem and bast residues represent a promising source of lignocellulosic fiber. In recent years, considerable attention has been directed toward the utilization of okra bast fiber (OBF) as a sustainable reinforcement and textile fiber because of its cellulose-rich composition, satisfactory mechanical properties, relatively low density and potential for value addition to agricultural waste. This review summarizes reported studies on the chemical composition, physical characteristics, mechanical performance, thermal stability, surface morphology, crystallinity and chemical modification of okra bast fiber. Fiber properties are influenced by plant maturity, extraction and retting methods, as well as chemical treatments such as scouring, bleaching and alkalization. Raw okra fibers have been reported to exhibit good tensile strength and colour fastness, while chemical treatments can modify surface morphology, cellulose content, diameter, tensile properties and thermal behaviour. Studies on hybrid composites have further indicated that okra fiber can contribute positively to tensile, flexural and impact performance. Overall, the paper indicates that okra bast fiber has considerable potential for textile, nonwoven, composite and other sustainable material applications.*

### Keywords

Okra bast fiber, Crystallinity, Composite, Thermal Stability and Surface modification.

**Centre For Studies of National Development, Meerut**

Editorial Office : D-59, Shastri Nagar, Meerut - 250 004 (INDIA)

Ph. : 0121-2763765, +91-9997771669, +91-9412200765

## **Harnessing the Potential of ‘Okra Bast Fiber’ for Technical Textile Applications**

### **1. Introduction**

The increasing demand for renewable and environmentally sustainable materials has encouraged research into natural fibers obtained from agricultural crops and their residues. Natural lignocellulosic fibers are attractive because they are renewable, biodegradable and comparatively lightweight, while also possessing useful mechanical and functional characteristics (Kumar *et al.*, 2021). Among the various agricultural fibers, okra bast fiber (OBF), obtained from the stem of *Abelmoschus esculentus*, has emerged as a potential material for textile and composite applications.

Okra is widely cultivated as a vegetable crop, and its stem remains largely underutilized after harvesting. The bast portion of the stem contains fibrous bundles that can be extracted and processed for different end uses. The properties of OBF are primarily associated with its lignocellulosic constituents, particularly cellulose, hemicellulose and lignin. The proportion of these constituents can vary depending on plant maturity, extraction technique, retting conditions and subsequent chemical treatment (Kolte and Shivankar, 2024).

Several researchers have investigated the chemical composition and performance of okra fiber. Alam and Khan (2007) reported a high  $\alpha$ -cellulose content in OBF and demonstrated that the fiber possesses useful colour fastness and tensile characteristics. Subsequent studies have examined the influence of harvesting age, retting method, chemical treatment and fiber location within the plant on its physical and mechanical properties (Stawski *et al.*, 2020; Dayan *et al.*, 2020). More recent investigations have also focused on the thermal, crystalline and morphological characteristics of the fiber and its application as reinforcement in polymer composites (Kolte and Shivankar, 2024).

The objective of this review is to consolidate the available findings concerning the physicochemical, mechanical, thermal and morphological characteristics of okra bast fiber and to discuss the influence of processing and chemical treatments on its performance.

### **2. Chemical Composition of Okra Bast Fiber**

The chemical composition of a natural fiber plays a major role in determining its mechanical strength, moisture absorption, thermal stability, dyeability and chemical reactivity. Cellulose provides the principal structural framework and contributes significantly to fiber strength, whereas hemicellulose, lignin and pectic substances influence flexibility, surface characteristics and resistance to environmental conditions.

Alam and Khan (2007) investigated the physicochemical composition of okra bast fiber and reported 67.5%  $\alpha$ -cellulose, 15.4% hemicellulose, 7.1% lignin, 3.4% pectic matter, 3.9% fatty and waxy matter and 2.7% aqueous extract. The comparatively high  $\alpha$ -cellulose content indicates the suitability of OBF for applications where cellulose-based mechanical and textile characteristics are desirable. The researchers further associated the high cellulose content and molecular weight of OBF with favourable dyeability, tensile strength and colour fastness.

A similar cellulose-rich composition was reported by Kolte and Shivankar (2024), who stated that okra fiber principally contains approximately 60-70% cellulose and 15-20% hemicellulose, together with pectin, lignin, fats, waxes and other water-soluble compounds. Although the exact chemical composition varies among studies, the results consistently demonstrate that cellulose constitutes the major component of OBF.

Vasugi *et al.* (2019) also demonstrated that processing can substantially alter the chemical composition of okra fiber. The  $\alpha$ -cellulose content of untreated fiber was reported to be 65.7%, increasing to 88.8% after scouring and bleaching. This increase can be attributed to the removal of non-cellulosic constituents during processing. Such removal is important because hemicellulose, lignin, pectin, waxes and other surface impurities can interfere with fiber-matrix bonding and affect dyeing, wettability and surface uniformity. Thus, it can be said that OBF is a cellulose-rich natural fiber whose properties can be significantly modified through appropriate purification and chemical treatments.

### **3. Physical and Mechanical Properties**

The mechanical performance of natural fibers is influenced by their cellulose content, degree of crystallinity, fiber diameter, maturity, extraction method and processing conditions. Okra fiber has demonstrated useful tensile characteristics, although considerable variation has been observed depending on the age and location of the fiber within the plant.

Dayan *et al.* (2020) investigated the physio-mechanical properties of okra fiber obtained at different harvesting ages. Four-month-old okra fiber exhibited a strength of 30.78 g/tex and a fineness of 40.50  $\mu$ m, whereas six-month-old fiber showed a higher strength of 31.98 g/tex but greater fineness value of 56.12  $\mu$ m. The whiteness or colour values were reported as 48.40% and 43.56% for four- and six-month-old fibers, respectively. These findings demonstrate that harvesting age can influence the physical and mechanical characteristics of OBF. The improvement in strength at greater maturity may be related to changes in the development and organization of the fiber's structural components.

Stawski *et al.* (2020) examined okra fibers obtained from different parts of the plant using water and dew retting methods. Fibers collected from the upper part of the plant showed higher breaking strength and lower linear density. Furthermore, water-retted fibers demonstrated higher breaking strength and elongation at break,

together with lower linear density, compared with fibers obtained through dew retting. These results demonstrate that both fiber position and retting technique can have a significant influence on the resulting fiber quality. And in a study conducted by Hossen *et al.* (2021), reported that the fiber exhibited rigid breaking characteristics. The researchers associated this behaviour with the presence of lignin on the fiber surface. The mechanical response of OBF is therefore not governed solely by cellulose content but is also affected by the presence and distribution of non-cellulosic constituents.

## **4. Structural, Morphological, Chemical and Thermal Characteristics**

### **4.1 Surface Morphology**

Surface morphology is an important factor in determining the performance of natural fibers, particularly when they are used as reinforcement in polymer composites. A rough and irregular surface can provide mechanical interlocking with a polymer matrix, whereas excessive surface impurities can reduce effective interfacial bonding.

Scanning electron microscopy (SEM) observations reported by Hossen *et al.* (2021) showed that the longitudinal surface of okra fiber consisted of overlapping cells, while the cross-sectional view displayed an uneven polygonal structure. These morphological characteristics reflect the natural organization of the fiber bundles and contribute to the physical behaviour of OBF. Vasugi *et al.* (2019) also observed that untreated okra fiber had a hairy and relatively rough surface. Following scouring and bleaching, the surface became considerably more uniform. The removal of surface impurities and non-cellulosic materials through chemical processing therefore produced a cleaner and more homogeneous fiber surface. The morphological changes produced by chemical treatments are particularly relevant for composite applications because modification of the fiber surface can improve interaction between the hydrophilic natural fiber and a relatively hydrophobic polymer matrix.

### **4.2 Fourier Transform Infrared Spectroscopy and Functional Groups**

Fourier Transform Infrared Spectroscopy (FTIR) is commonly employed to identify the functional groups present in lignocellulosic fibers and to evaluate chemical changes resulting from processing. Dayan *et al* (2020) used FTIR analysis to characterize okra fiber obtained at different harvesting ages and confirmed the presence of characteristic functional groups associated with its lignocellulosic structure.

The presence of cellulose, hemicellulose and lignin-related functional groups contributes to the characteristic chemical behaviour of OBF. Changes in the intensity or presence of specific absorption bands after chemical treatment can indicate the removal or modification of non-cellulosic components. Consequently,

FTIR analysis provides useful evidence for evaluating the effectiveness of scouring, bleaching and other surface modification processes.

### **4.3 Thermal Properties**

Thermal stability is a critical property when natural fibers are intended for composite processing or applications involving elevated temperatures. Because lignocellulosic fibers contain different constituents that degrade at different temperatures, thermal analysis is necessary to establish their processing limitations.

Dayan *et al.* (2020) employed thermogravimetric analysis (TGA) to study okra fibers of different ages. Their findings showed that the six-month-old fiber exhibited better thermal stability than the four-month-old fiber. The difference was attributed to changes associated with fiber maturation.

Kolte and Shivankar (2024) reported that gradual degradation of okra fiber became evident after approximately 240°C. Their results indicate that OBF can withstand moderate processing temperatures but may experience significant thermal degradation at higher temperatures. Therefore, when OBF is incorporated into thermoplastic or thermosetting composites, processing conditions should be selected carefully to minimize thermal damage to the natural reinforcement.

The available thermal studies suggest that maturity and chemical composition affect the thermal behaviour of OBF, while the onset of degradation must be considered when selecting suitable matrices and processing temperatures.

### **4.4 Crystallinity and X-Ray Diffraction Analysis**

The crystalline structure of cellulose is closely related to the stiffness, strength, moisture absorption and chemical reactivity of natural fibers. X-ray diffraction (XRD) is therefore an important analytical technique for evaluating the crystalline and amorphous regions of lignocellulosic fibers.

Hossen *et al* (2021) reported that the basic crystal structure of okra fiber was triclinic. Kolte and Shivankar (2024) further reported approximately 74.2% crystalline and 25.8% amorphous regions in okra fiber. The relatively high crystalline fraction indicates a substantial degree of structural organization within the cellulose component.

According to Kolte and Shivankar (2024), the high crystalline fraction influences the water absorption capacity, elongation and chemical reactivity of the fiber. Higher crystallinity generally indicates a more ordered cellulose structure, which can contribute to mechanical strength but may also influence moisture penetration and accessibility of reactive chemical groups.

## **5. Effect of Alkali Treatment**

Chemical modification is frequently used to improve the performance of natural fibers by removing non-cellulosic constituents and altering their surface characteristics. Alkali treatment, particularly sodium hydroxide (NaOH), is one of

the most widely studied treatments because it can remove portions of hemicellulose, lignin, waxes and other surface impurities.

Duman *et al.* (2017) investigated okra stem waste treated with 10% NaOH at 60°C for treatment durations of 10, 20, 30 and 40 minutes. The alkali treatment decreased both fiber weight and diameter while increasing tensile strength and elongation. This indicates that NaOH treatment altered the fiber structure by removing non-cellulosic materials and modifying the fiber surface. The researchers also produced nonwoven materials from treated and untreated okra fibers and evaluated their thermal conductivity. Among the NaOH-treated nonwoven samples, the fiber treated for 10 minutes exhibited the best heat-transfer coefficient. However, the study reported no clear correlation between treatment duration and heat-transfer coefficient. This suggests that thermal performance is affected by several interacting structural factors rather than treatment duration alone.

Khan *et al.* (2019) also evaluated chemical treatments of okra bast and corn husk fibers, including alkalization, bleaching, maleic anhydride and vinyl acetate treatments. Their results showed that alkaline treatment decreased tensile stiffness and tenacity while increasing elongation. Both okra bast and corn husk fibers exhibited their highest mechanical strength following vinyl acetate treatment and bleaching. The authors further concluded that corn husk fiber was more susceptible to chemical treatment than okra bast fiber.

These findings demonstrate that chemical treatment should be carefully optimized because excessive removal or modification of structural components may improve some properties while reducing others.

## **6. Effect of Scouring and Bleaching on Colour, Fastness and Dyeability**

Scouring and bleaching are important pretreatment processes for improving the appearance, cleanliness and dyeing performance of natural fibers. In okra bast fiber (OBF), these treatments remove surface impurities and non-cellulosic constituents such as waxes, pectins, hemicellulose and portions of lignin, thereby modifying the surface characteristics and chemical composition of the fiber. Vasugi *et al.* (2019) reported that untreated okra fibers had a dull appearance, whereas scouring and bleaching considerably improved their brightness. The brightness of the fiber increased by approximately 92% after scouring and by 20% after bleaching. The  $\alpha$ -cellulose content also increased from 65.7% in the raw fiber to 88.8% after scouring and bleaching, indicating the effective removal of non-cellulosic components during pretreatment. SEM observations further showed that the untreated fiber had a hairy and rough surface, while the scoured and bleached fibers exhibited a cleaner and more uniform surface.

The removal of surface impurities during scouring and bleaching can also influence the dyeability of OBF. A cleaner and more hydrophilic fiber surface facilitates the penetration and interaction of dyes with the cellulose-rich structure of

the fiber. The relatively high  $\alpha$ -cellulose content of OBF provides abundant hydroxyl groups that can participate in interactions with suitable textile dyes. Alam and Khan (2007) reported that okra bast fiber possessed good dyeability, which was associated with its high  $\alpha$ -cellulose content and molecular weight. Thus, removal of non-cellulosic substances during pretreatment can improve the accessibility of the cellulose structure and may contribute to more uniform dye uptake.

However, improvement in brightness and dyeability does not necessarily result in improved colour fastness. Alam and Khan (2007) investigated the colour fastness of bleached and unbleached OBF under sunlight exposure and found that the raw, unbleached fiber exhibited higher colour fastness than the bleached fiber. This suggests that bleaching may modify the chemical structure or surface characteristics of the fiber in a manner that affects the retention of colour during exposure to light. Therefore, pretreatment conditions should be carefully optimized to achieve a suitable balance between brightness, cleanliness, dyeability and colour fastness.

The combined findings indicate that scouring and bleaching can substantially improve the aesthetic and chemical characteristics of OBF by increasing brightness, removing surface impurities and increasing the relative cellulose content. At the same time, the treatments can alter the dyeing and colour-fastness behaviour of the fiber.

## **7. Application of Okra Fiber in Technical Textiles**

OBF has considerable potential as a reinforcement in polymer composites, widely used technical textile now-a-days. The use of okra bast fiber as reinforcement in polymer composites has received increasing attention because of its renewable origin, low density and cellulose-rich structure. And also, natural-fiber-reinforced polymer composites offer an alternative to conventional synthetic-fiber composites because agricultural residues can be converted into value-added engineering materials.

Rosa *et al.* (2010) investigated the morphological, thermal and mechanical characteristics of okra (*Abelmoschus esculentus*) fibers and assessed their potential as reinforcement in polymer composites. Their study demonstrated that okra fibers possess characteristics suitable for use as a natural reinforcement, while also highlighting the importance of fiber morphology and thermal behaviour in determining composite performance.

Similarly, Potluri *et al.* (2017) investigated the mechanical properties of okra-fiber-based green composites and hybrid laminates. The researchers fabricated okra-fiber-reinforced epoxy composites and evaluated their mechanical behaviour. The study demonstrated the feasibility of incorporating okra fiber into a polymer matrix to produce green composite materials. The mechanical performance of the resulting composites was influenced by fiber content, fiber arrangement and interaction between the fiber and epoxy matrix. The study therefore established the potential of okra fiber as a renewable reinforcement for polymer composite applications.

Rahman *et al.* (2018) investigated the fabrication, mechanical characteristics and interfacial properties of okra-fiber-reinforced polypropylene composites. In their work, polypropylene was used as the polymer matrix and the okra fiber content was varied from 25 to 65% of the total composite weight. The investigation focused on the effect of fiber loading on the mechanical behaviour and fiber-matrix interfacial characteristics. The study is particularly important because polypropylene is a widely used thermoplastic matrix, demonstrating that okra fiber is not limited to thermosetting resin systems and can also be considered for thermoplastic composite applications.

The interface between the natural fiber and polymer matrix is a critical factor controlling the performance of OBF-reinforced composites. Because okra fiber contains hydrophilic cellulose and other polar constituents, its compatibility with relatively hydrophobic polymer matrices can be limited. Consequently, fiber surface treatment and appropriate processing are important for improving interfacial adhesion. Removal of waxes, pectin, hemicellulose and other surface impurities can increase the accessibility of cellulose and modify the fiber surface, potentially improving mechanical load transfer between the fiber and polymer matrix. This is particularly relevant for okra/polypropylene and okra/epoxy composites, where the quality of the fiber-matrix interface can strongly influence tensile and flexural behaviour (Rahman *et al.*, 2018; Potluri *et al.*, 2017).

Hybridization provides another approach for improving the performance of okra-fiber composites. Kumar *et al.* (2021) developed okra/sisal/polyester hybrid composites using different okra-to-sisal fiber ratios. The results showed that the hybrid composites possessed useful impact and flexural properties, while increasing the proportion of okra fiber improved flexural performance. The study also reported an increase in tensile and impact strength with increasing fiber weight fraction. These findings indicate that combining okra with another natural fiber can provide a means of balancing the mechanical properties of the resulting composite and broadening the potential applications of OBF-based materials.

More recently, Raja *et al.* (2026) characterized *Abelmoschus esculentus* plant-waste fiber for sustainable composite and biomedical applications. The study examined the physicochemical, structural and functional characteristics of okra plant waste and highlighted its potential as a sustainable fiber source. The research further supports the utilization of okra agricultural residues in value-added materials rather than treating the stem as waste. The authors emphasized the relevance of the fiber for sustainable composite development, demonstrating the continuing interest in okra-derived lignocellulosic materials for advanced applications.

## 8. Conclusion

Okra bast fiber is a promising lignocellulosic material with potential applications in textiles, nonwovens, thermal materials and polymer composites.

The literature demonstrates that OBF is characterized by a relatively high -cellulose content, together with hemicellulose, lignin, pectin, waxes and water-soluble components. Its mechanical properties are influenced by fiber maturity, plant location, retting technique and chemical treatment.

Raw OBF has demonstrated good tensile strength and colour fastness, while scouring and bleaching can increase brightness, cellulose content and surface uniformity. Alkali treatment can reduce fiber diameter and alter tensile behaviour, whereas other chemical modifications can improve mechanical performance depending on treatment conditions. Thermal and XRD studies further indicate that fiber maturity and crystallinity influence thermal stability and structural behaviour.

The successful incorporation of okra fiber into okra/sisal/polyester hybrid composites demonstrates its potential as a renewable reinforcement material. Overall, the current study establishes OBF as a valuable agricultural residue that can be converted into functional materials. Future work should focus on standardized extraction and treatment methods, environmentally sustainable processing, long-term durability and optimization of OBF for specific industrial and textile applications.

## References

- Alam, M S and Khan G M A, "Chemical analysis of okra bast fiber (*Abelmoschus esculentus*) and its physico-chemical properties", *Journal of Textile and Apparel, Technology and Management*, 5(4), (2007), 1-9.
- Dayan, M A R, Habib M M, Kaysar M A and Uddin M M, "Study on the physico-mechanical properties of okra fibre at different harvesting time", *Saudi Journal of Engineering and Technology*, 5(8), 2020, 304-309. <https://doi.org/10.36348/sjet.2020.v05i08.002>
- Duman, M N, Kocak E D, Merdan N and Mistik I, "Nonwoven production from agricultural okra wastes and investigation of their thermal conductivities", *IOP Conference Ser: Mater Sci Eng*, 254, 2017, 116-23.
- Hossen, M T, Islam T, Mahee E I, Reza Z T, Rahman M and Mahmud M S, "A comprehensive study on physico-mechanical characteristics of okra fibre (*Abelmoschus esculentus*) for textile applications", *Indian Journal of Science and Technology*, 14(9), 2021, 765-75. <https://doi.org/10.17485/IJST/v14i9.2268>.
- Khan, G M A, Yilmaz N D and Yilmaz K., "Effect of chemical treatments and degumming methods on physical and mechanical properties of okra bast and corn husk fibers", *The Journal of The Textile Institute*, 111(10), 2020, 1418-35. <https://doi.org/10.1080/00405000.2019.1702492>.
- Kolte, P and Vijay S, "Critical investigation of *Abelmoschus esculentus* (Indian okra) fiber characteristics", *Research Square*, 2022. <https://doi.org/10.21203/rs.3.rs-2210815/v1>.
- Potluri, R, Paul K J, Kalam S A and Prasanthi P, "Mechanical properties characterization of okra fiber based green composites & hybrid laminates", *Materials Today: Proceedings*, 4(2), 2017, 2893-902. <https://doi.org/10.1016/j.matpr.2017.02.170>.
- Rahman, A N M M, Alimuzzaman S, Khan R A, Khan M E and Hoque S N, "Fabrication, mechanical characterization and interfacial properties of okra fiber reinforced polypropylene composites", *International Journal of Engineering Materials and Manufacture*, 3(1), 2018, 18-31. <https://doi.org/10.26776/ijemm.03.01.2018.03>.

- Rosa, I M D, Kenny J M, Puglia D, Santulli C and Sarasini F, “Morphological, thermal and mechanical characterization of okra (*Abelmoschus esculentus*) fibres as potential reinforcement in polymer composites”, *Composites Science and Technology*, 70(1), 2010, 116-22. <https://doi.org/10.1016/j.compscitech.2009.09.013>.
- Stawski, D, Çaliskan E, Yilmaz N D and Krucińska I, “Thermal and mechanical characteristics of okra (*Abelmoschus esculentus*) fibers obtained via water- and dew-retting”, *Applied Sciences*, 10(15), 2020, 5113. <https://doi.org/10.3390/app10155113>.
- Vasugi, N, Amsamani S and Sunitha R, “Extraction and evaluation of OKRA fibres”, *International Journal of Polymer Textile Engineering*, 6, 2019, 24-30
- Raja, T, Devarajan Y, Kalidhas A M, Sandeep G M, Saxena M, Choudhury S, Dhorajiya A and Mehar K, “Characterization of *Abelmoschus esculentus* plant waste fiber for sustainable composite and biomedical applications”, *Scientific Reports*, 16:8763, 2026. <https://doi.org/10.1038/s41598-026-39438-y>. ★