**International Journal of Health Technology and Innovation** RESEARCH ARTICLE
An Official Journal of **Kalam Institute of Health Technology** | ISSN - **2583-8547**

# Combined Fiber of Polyester and Bamboo for Prosthetic Socks for Better Absorbent and Antimicrobial Activity

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***Received: 28th January, 2024; Revised: 18th February, 2024; Accepted: 06th March, 2024; Available Online: 05th April, 2024***

**ABSTRACT**

Prosthetic socks, a crucial element in the comfort and well-being of individuals with prosthetic limbs, are the subject of our innovative study. We present a novel approach by combining bamboo and polyester fibers to manufacture these socks. Bamboo, renowned for its eco-friendliness and natural properties, provides antibacterial, anti-allergic, and anti-irritant benefits while requiring minimal water for cultivation. Polyester, a synthetic polymer, boasts hydrophobic characteristics, ensuring quick drying and remarkable durability. By merging these materials, we create prosthetic socks that offer a unique blend of advantages. The socks combat skin infections caused by excessive sweating due to bamboo's antimicrobial properties, while polyester contributes to moisture-wicking and rapid drying.

Furthermore, the socks promise enhanced comfort, softness, and durability, catering to the active lifestyle demands of prosthetic users. This study aims to determine the effectiveness of prosthetic socks in preventing the growth of bacteria and fungi that can cause odor and infection while also enhancing quick drying and high absorbency properties. The research will evaluate the performance of different prosthetic socks through laboratory testing and user feedback surveys. The findings will provide valuable insights into improving prosthetic socks' design and functionality, ultimately enhancing amputees' quality of life. Additionally, it seeks to evaluate the performance enhancements related to quick drying and high absorbency properties. Additionally, the research explores the socks' quick-drying and high-absorbency properties, which are crucial factors in maintaining hygiene and comfort for prosthetic wearers. Overall, this investigation presents a promising solution that addresses practical concerns associated with prosthetic socks and aligns with sustainability goals by integrating natural and synthetic materials.

For this, there is a possible way to combine polyester and bamboo fibers to enhance prosthetic socks' absorbent and antimicrobial properties, improving overall comfort and hygiene for the wearer.

**Keywords:** Antibacterial properties, Bamboo fiber, Biodegradable materials, Eco-friendly materials, Prosthetic socks, Polyester fiber.

International Journal of Health Technology and Innovation (2024)

**How to cite this article:** Ganesh V, Arun D, Das M, Indra C, Anzzalee K. Combined Fiber of Polyester and Bamboo for Prosthetic Socks for Better Absorbent and Antimicrobial Activity. International Journal of Health Technology and Innovation. 2024;3(1):34-39.

**Doi:** 10.60142/ijhti.v3i01.06

**Source of support:** Nil.

**Conflict of interest:** None

## INTRODUCTION

This comprehensive study highlights the prevalence of various dermatologic conditions among lower extremity amputees who use prostheses, including ulcers, irritation, inclusion cyst, callus, and verrucous hyperplasia, which constitute the majority of observed skin lesions.[1] It underscores the importance of collaborative care between prosthetists and physicians in addressing these conditions, emphasizing the need for prospective research to understand better the relationship between skin problems, residual limb characteristics, preventive measures, and management strategies tailored to the specific needs of amputees.[2] The effects of various prosthetic socks on the tribological behaviors, mechanical irritations, and comfort sensations of stump skin

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underscore the pivotal role of fabric weave, surface features, and material composition in mitigating friction-related injuries and enhancing wearer comfort.[2] the comfort properties of socks crafted from a range of novel fibers, including modal, micro modal, bamboo, soybean, and chitosan, alongside conventional options like cotton and viscose. Findings indicate that factors such as fiber type, fabric thickness, and regain significantly influence comfort-related attributes such as water vapor transfer, air permeability, wicking, wetting, and heat transfer, suggesting the potential for tailored combinations of fiber blends to optimize comfort for different end uses.[3]

Including polyester yarn in the moisture-transferring layer of prosthetic socks could significantly enhance hygienic quality and comfort for individuals with lower limb amputations. This recommendation is based on the advantageous properties of polyester yarn, including its ability to transfer moisture away from the skin effectively. This helps decrease the likelihood of skin irritation and enhances overall comfort for the wearer.[4] By harnessing polyester yarn's moisture-wicking capabilities in prosthetic socks, manufacturers can potentially enhance prosthetic devices' overall performance and usability, ultimately benefiting amputees in their daily lives.[4] The versatility of bamboo fibers extends beyond traditional applications, with current research focusing on their potential to replace non-renewable resources like glass fiber, thus promoting economic sustainability and eco-friendly practices. Bamboo fiber-based biocomposites offer a promising avenue for developing green, high-performance materials with desirable functionalities for various industrial sectors by optimizing processing parameters and enhancing interfacial adhesion.[5]

## MATERIALS AND METHOD

### Antimicrobial Property

The investigation into the antibacterial properties of Australian-grown bamboo delved deep into the realm of natural materials for potential antimicrobial applications. Employing a meticulous methodology, researchers utilized various solvents to extract critical components from the bamboo, aiming to uncover potent antibacterial agents. One of the primary extraction methods involved using dimethyl sulfoxide (DMSO) to isolate hemicellulose, a complex carbohydrate found in plant cell walls.[6] The resulting extract exhibited notable antibacterial activity, indicating the presence of bioactive compounds within the hemicellulose fraction. While this extract inhibited bacterial growth, it failed to completely eradicate the bacteria under study.[7]

In contrast, the extraction process using aqueous dioxane for milled wood lignin (MWL) yielded remarkable results. The obtained extract inhibited bacterial growth and demonstrated complete antibacterial activity even upon extensive dilution. This observation hinted at the presence of a highly potent antibacterial compound within the lignin fraction of the bamboo. Methods for chemical analysis, like fourier transform infrared spectroscopy (FTIR), played a crucial role in unraveling the molecular components responsible for the antibacterial properties.[8] The FTIR analysis revealed the presence of aromatic and phenolic functional groups in lignin, suggesting their potential involvement in conferring antibacterial activity. These findings underscored the intricate chemistry of bamboo-derived compounds and their promising role as natural antibacterial agents. Moreover, the study shed light on the potential applications of lignin-rich materials in developing novel antimicrobial strategies, paving the way for further exploration and utilization of sustainable resources in combating bacterial infections.[9] Figure 1: Chemical Constituents of Bamboo" likely depicts the various compounds present in bamboo that contribute to its unique properties. This could include cellulose, hemicellulose, lignin, silica, and various organic acids. These constituents are essential in providing bamboo with its strength, durability, and antimicrobial properties.

### Procedure

*Preparation procedure for combined fiber*

The combined fiber preparation process is a meticulous endeavor that begins with extracting bamboo yarns from specially crafted bamboo towels. Bamboo, known for its exceptional moisture-wicking capabilities and natural antibacterial properties, is the foundation of this innovative approach. These inherent qualities make bamboo ideal for applications of comfort and hygiene, such as prosthetic socks, are paramount. Once the bamboo yarns are obtained, they are combined with polyester yarns to create a synergistic blend. Polyester, prized for its remarkable strength and resilience, complements the bamboo fibers, adding a crucial element of durability to the fabric.[10] The blending process involves pairing one bamboo yarn with one polyester yarn, a strategic decision to maximize each material's benefits.

This pairing results in a fiber that inherits a unique set of properties from bamboo and polyester. Bamboo's moisture-wicking prowess and antibacterial benefits are seamlessly integrated, offering effective moisture management and inhibiting microbial growth. At the same time, the strength and resilience of polyester enhance the fabric's durability, ensuring long-lasting wear comfort.[11]

Combining these two materials creates a balanced blend that excels in softness, breathability, and longevity. Users of prosthetic socks made from this synergistic blend can expect unparalleled comfort and performance. The fabric effectively manages moisture, keeping the skin dry and comfortable, while its antibacterial properties help maintain hygiene and prevent odors. Furthermore, the durability of the blend ensures that the socks can withstand the rigors of daily wear, providing users with lasting comfort and confidence.[12]

The combined fiber preparation process represents a harmonious fusion of natural and synthetic materials, leveraging the best of both worlds to create a superior product. By carefully blending bamboo and polyester yarns, manufacturers can offer prosthetic socks that meet and exceed users' expectations, enhancing their overall quality of life.[13]

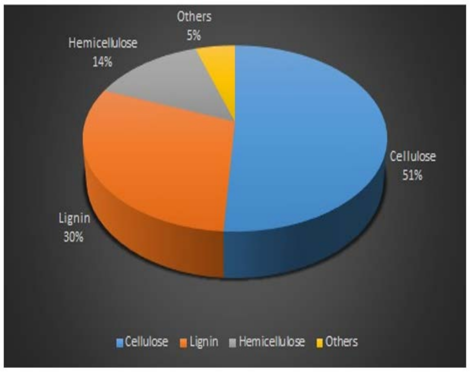


**Figure 1:** Chemical constituents of bamboo

*Analysis of tensile strength*

Assessing tensile strength is pivotal in understanding the mechanical properties and performance capabilities of the combined polyester and bamboo fiber and the individual polyester and bamboo yarns. Figure 2 showcases the visual comparison of (a) polyester yarn, (b) bamboo yarns, and (c) the combination of bamboo and polyester threads, providing a comprehensive overview of the different yarn compositions utilized in the study. This evaluation process involves a systematic approach to ensure accuracy and reliability in the results obtained. Initially, samples of the combined fiber, along with the polyester and bamboo yarns, are carefully prepared by cutting them into standardized lengths of 6 cm. [14]

Subsequently, the samples are subjected to rigorous testing using a sophisticated universal testing machine (UTM), which operates at a controlled speed of 20 mm/min. Figure 3 depicts the tensile strength test of bamboo fibers conducted with a UTM, offering insight into the mechanical characteristics of the bamboo material. This controlled speed ensures that all samples' testing conditions remain constant, minimizing external factors influencing the results. Before initiating the testing procedure, careful precision aligns the samples parallel to the load cell direction within the UTM grip. Achieving accurate alignment is crucial to ensure uniform distribution of the applied force along the length of the sample, thereby mitigating any potential bias in the results. Furthermore, the UTM is calibrated to use a standardized thickness or width of 0.55 mm for the samples.[15]

This standardization ensures uniformity in the testing conditions, allowing for accurate and reliable tensile strength measurements. As the UTM initiates the tensile testing process, the behavior of the samples is closely monitored and observed. Figure 4 illustrates the results of the tensile strength test conducted on the combined bamboo and polyester fibers utilizing a UTM, visually representing the material's mechanical properties. Researchers pay particular attention to any signs of deformation, elongation, or failure exhibited by the samples during the testing procedure. The maximum force required to break each sample is recorded in Newtons (N). This quantitative data provides valuable insights into the tensile strength of the combined polyester and bamboo fiber and the individual polyester and bamboo yarns (Figure 5).


**Figure 2:** a) Polyester yarn, b) Bamboo yarns, c) Bamboo and polyester combined thread

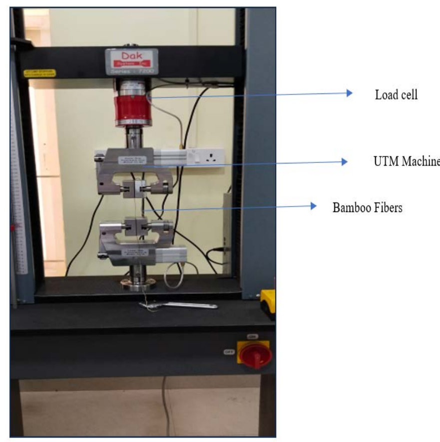


**Figure 3:** Bamboo fibers tensile strength test by using UTM machine

These insights are crucial for assessing the suitability of the materials for various applications, such as prosthetic socks and other textile products, where durability and resilience are paramount.[16]

## RESULTS

This excerpt outlines a comparison of three sample - polyester, combination, and bamboo based on their tensile properties. Let's break down each aspect and elaborate on its significance:

### Width and Thickness

he identical width and thickness dimensions of 0.550 mm for all three samples ensure consistency in testing conditions. This standardization is crucial for accurate comparison, as it eliminates variations in geometry that could influence test results. It allows for a fair assessment of the material's tensile properties without the confounding factor of differing dimensions.[17]

### Testing Speed

Conducting tensile tests at a constant speed of 30.000 mm/min across all samples ensures uniformity in the testing process. Consistent testing speed minimizes the impact of testing variables on the results, such as strain rate effects.

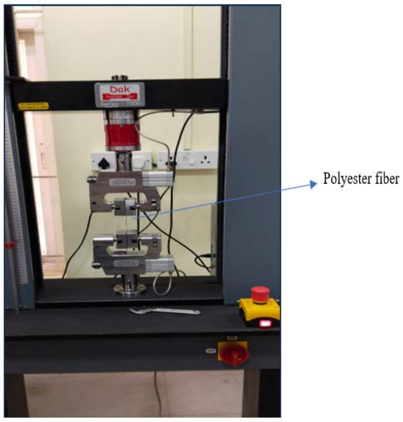


**Figure 4:** Polyester fibers tensile strength test by using UTM machine

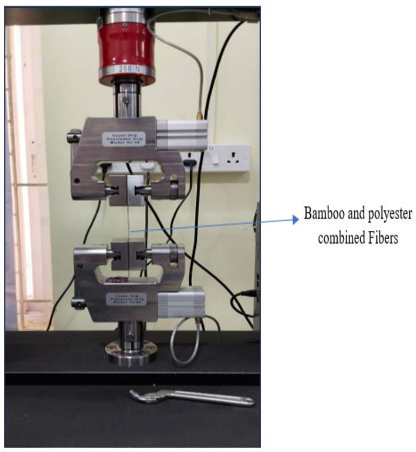


**Figure 5:** Bamboo and polyester combined fibers tensile strength test using UTM machine

[18] Consistently maintaining the testing speed allows any disparities in tensile behavior to be attributed to the inherent material properties rather than variations in testing conditions.

### Cross-Sectional Area

The determination of the cross-sectional area of each sample as 0.303 square millimeters provides a standardized basis for evaluating tensile strength. The cross-sectional area is a critical parameter in calculating tensile strength, as it normalizes the force applied to the material by its location. Standardizing the cross-sectional area (CSA) allows for directly comparing tensile strength values between different samples, facilitating meaningful analysis and interpretation of results.[19]

### Peak Load

Table 1 presents the results of the tensile strength testing conducted as part of this research study, providing a comprehensive overview of the mechanical properties of the investigated materials. The peak load indicates the maximum force applied to each sample before failure. In this comparison, the polyester sample exhibited the highest peak load of 35.4 N, followed by the combination sample with 19.8 N and the bamboo sample with 11.6 N.[20] The significant variation in peak load among the samples indicates differences in their

**Table 1:** Tensile strength testing results

| *Sample name* | *Width (mm)* | *Thick ness (mm)* | *Speed (mm/ min)* | *CSA (sq. com)* | *Peak load (N)* | *Tensile strength (Mpa)* |
|---|---|---|---|---|---|---|
| Combi nation | 0.550 | 0.550 | 30.000 | 0.303 | 19.8 | 65.548 |
| Poly ester | 0.550 | 0.550 | 30.000 | 0.303 | 35.4 | 117.133 |
| Bam boo | 0.550 | 0.550 | 30.000 | 0.303 | 11.6 N | 38.255 |

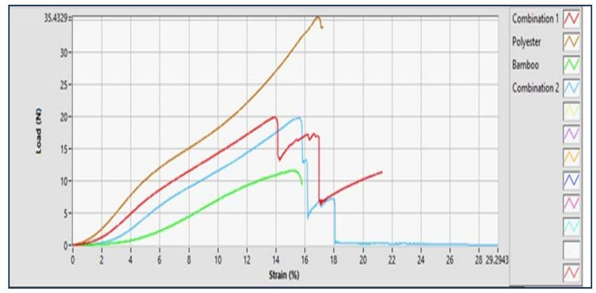


**Figure 6:** Tensile strength reports based on different fibers

ability to withstand tensile forces. The polyester sample's higher peak load suggests superior strength compared to the Combination and Bamboo samples.

### Tensile Strength

Tensile strength, calculated as the peak load divided by the cross-sectional area, provides insight into the material's ability to withstand stretching or pulling forces. The polyester sample demonstrated the highest tensile strength at 117.133 MPa, followed by the combination sample at 65.548 MPa and the bamboo sample at 38.255 MPa. Tensile strength is a core mechanical property that measures a material's ability to withstand tensile forces.[21] The higher tensile strength of the polyester sample indicates its superior performance under tensile loading compared to the combination and bamboo samples.

## DISCUSSION

Figure 6 displays the varied tensile strength reports derived from different fiber compositions, highlighting the diverse mechanical performance of the tested materials. The provided data offers a succinct comparison of three distinct samples – Combination, polyester, and bamboo – focusing on their tensile properties. Polyester is the standout performer, showcasing the highest peak load of 35.4 N and a remarkable tensile strength of 117.133 MPa. These figures signify polyester's exceptional ability to withstand stretching and pulling forces, positioning it as a robust material choice for applications requiring high mechanical strength.

In contrast, the combination demonstrates a moderate peak load of 19.8 N and corresponding tensile strength of 65.548 MPa. While not as impressive as polyester, the combination exhibits respectable mechanical properties suitable for various engineering purposes. On the other hand, bamboo displays the lowest peak load of 11.6 N and a comparatively lower tensile strength of 38.255 MPa. Despite its eco-friendly appeal and other desirable characteristics, bamboo needs to improve its tensile performance compared to polyester and combination.

These findings underscore the critical role of material selection in engineering design, particularly in load-bearing applications. The superior tensile properties of polyester highlight its suitability for demanding environments where structural integrity is paramount. Conversely, while combination and bamboo may offer other advantages such as sustainability or cost-effectiveness, their inferior tensile characteristics suggest they may be better suited for applications with less stringent mechanical requirements.

## CONCLUSION

The tensile testing results indicate notable discrepancies in the mechanical attributes of the three samples. The polyester sample showcasing the highest peak load and tensile strength implies superior resilience against stretching and pulling forces compared to the combination and bamboo samples. These results emphasize the critical role of material selection across diverse applications, with polyester exhibiting advantageous mechanical traits for load-bearing purposes. Further scrutiny and experimentation may be necessary to delve into each sample's characteristics and potential practical applications.

## FUTURE SCOPE

Future research endeavors should focus on refining the fabrication processes and material compositions of polyester, combination, and bamboo to enhance their mechanical prowess. The potential to bridge the performance gap between polyester and its counterparts lies in exploring innovative reinforcement techniques and hybrid material combinations. Additionally, long-term durability studies are essential to elucidate how environmental factors influence the tensile properties of these materials over extended periods. Insights from such investigations would facilitate more informed material selection decisions in diverse engineering applications, ensuring optimal performance and longevity.

Moreover, integrating cutting-edge manufacturing technologies like additive manufacturing and nanotechnology promises to revolutionize the production processes of these materials. By harnessing the capabilities of such advanced techniques, researchers can unlock new avenues for improving mechanical characteristics while simultaneously addressing sustainability concerns. Embracing a holistic approach that considers mechanical properties and factors like thermal conductivity, chemical resistance, and recyclability is paramount. Through concerted efforts in these directions, the engineering community can usher in a new era of material innovation, meeting the evolving needs of industries while mitigating environmental impacts.

## LIMITATIONS

While the tensile testing results provide valuable insights into the mechanical properties of the polyester, combination, and bamboo samples, several limitations must be acknowledged. Firstly, the study focused solely on tensile strength as a measure of mechanical performance, neglecting other important attributes such as ductility, impact resistance, and fatigue strength. Therefore, the broader applicability of these materials across different loading conditions remains to be seen, warranting further investigation into their comprehensive mechanical behavior.

Additionally, the testing conditions may only partially replicate real-world scenarios, potentially leading to discrepancies between laboratory results and practical performance. Factors such as temperature, humidity, and strain rate variations could influence the material response differently in practical applications, necessitating more extensive testing under diverse environmental conditions. Moreover, the samples used in the study may only partially represent part of the range of polyester, combination, and bamboo materials available in the market, raising questions about the generalizability of the findings. Future research should include a broader sample size to accurately capture each material category's variability.

## ACKNOWLEDGEMENT

Sincere Thanks to Prof. USN Murty, Director, National Institute of Pharmaceutical Education and Research (NIPER)-Guwahati, for providing the facilities. We thank Prof. S Kanagaraj, Dr. Saurabh Kumar, Arun D, and Mayur K Das (who gave the problem statement) for their guidance and valuable feedback. Also, I am thankful to the charge research scholar of the Department of Medical Devices.

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