Fabrication of Ramie Fiber Reinforced CaO Nanoparticles Influenced Bio-Composite: an Antibacterial and Functional Analysis

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**Abstract:** This ponder explores the amalgamation and characterization of a novel bio-composite fabric strengthened with ramie fiber and calcium oxide (CaO) nanoparticles. The essential objective was to improve the antibacterial properties and generally usefulness of the bio-composite. The ramie fiber, known for its tall ductile quality and biodegradability, was treated to progress fiber-matrix grip some time recently being coordinated with CaO nanoparticles by means of a sol-gel preparation. The resultant bio-composite showed critical antibacterial movement against Staphylococcus aureus and Escherichia coli, which made strides in mechanical and warm properties. These discoveries recommend potential applications in restorative gadgets, bundling, and natural divisions. Be that as it may, encouraging investigation is required to optimize the definition, address impediments in fiber-matrix holding, and guarantee long-term steadiness and adaptability.

**Keywords**: Ramie fiber, CaO nanoparticles, bio-composite, antibacterial activity, mechanical properties, environmental sustainability.

# Introduction

The developing requirement for feasible materials with multifunctional properties has driven the investigation of common filaments fortified with nanoparticles [(Harsha & Subramanian, 2022)](https://paperpile.com/c/zABlZq/HoCk0)[(Deepika et al., 2022)](https://paperpile.com/c/zABlZq/zHLJk)[(Solanki et al., 2022)](https://paperpile.com/c/zABlZq/sjfpg). Ramie fiber, a bast fiber, is celebrated for its tall pliable quality, amazing biodegradability, and natural neighbourliness [(Chidambaram et al., 2022)](https://paperpile.com/c/zABlZq/EdZ3o).[(Ajay, Sasikala, et al., 2022)](https://paperpile.com/c/zABlZq/AUXMI). This ponders centres on creating a bio-composite fabric by fortifying ramie fiber with calcium oxide (CaO) nanoparticles to improve its antibacterial properties and by and large execution [[(Nicolais & Carotenuto, 2013)](https://paperpile.com/c/zABlZq/SUss)]. The joining of CaO nanoparticles points to address the common issue of bacterial development in composite materials, which is pivotal for applications within the restorative and natural segments[(Ajay, Rakshagan, et al., 2022)](https://paperpile.com/c/zABlZq/HQyMn). This investigation not as it were points to synthesize the bio-composite but moreover to conduct a comprehensive examination of its mechanical, warm, and antibacterial properties [[(Gadore et al., 2024)](https://paperpile.com/c/zABlZq/RbUi)]. The potential of this fabric in different applications, emphasizing the significance of optimizing the composite's union strategy to attain an adjustment between mechanical quality and antibacterial viability[(Ajay, Suma, et al., 2022)](https://paperpile.com/c/zABlZq/xSaVl) [(Katyal et al., 2021)](https://paperpile.com/c/zABlZq/VfX7b). The journey for maintainable and high-performance materials has picked up force in later a long time, driven by the double challenges of natural preservation and the require for progressed utilitarian materials [[(Das & Dhara, 2021)](https://paperpile.com/c/zABlZq/pas4)]. In this setting, the advancement of bio-composites, which coordinated characteristic filaments with manufactured or actually happening nanoparticles, speaks to a noteworthy step forward in fabric science[(Jabin et al., 2021)](https://paperpile.com/c/zABlZq/nLVLU)[(Balaji Ganesh S & Sugumar, 2021)](https://paperpile.com/c/zABlZq/kMCL6) [(Govindaraj & Dinesh, 2021)](https://paperpile.com/c/zABlZq/tOMCH) . These bio-composites offer a promising arrangement by combining the alluring properties of common filaments such as biodegradability and renewability with the upgraded utilitarian properties bestowed by nanoparticles [(Tiwari & Jain, 2023)](https://paperpile.com/c/zABlZq/TsiM7)[(Graf et al., 2023)](https://paperpile.com/c/zABlZq/kQ9WT). This synergistic approach not as it were makes a difference in moderating natural impacts but moreover opens up unused roads for applications in different divisions, counting medical, environmental, and bundling businesses [[(Sathish et al., 2021)](https://paperpile.com/c/zABlZq/QPnZ)]. Ramie (Boehmeria nivea) could be a bast fiber that has been utilized for centuries, especially in East Asia, where it is esteemed for its tall pliable quality, gloss, and resistance to microbial assaults[(Sabarathinam & Madhulaxmi, 2021)](https://paperpile.com/c/zABlZq/BU5iy)[(Sushanthi et al., 2021)](https://paperpile.com/c/zABlZq/SBi9k)[(Harsha et al., 2022)](https://paperpile.com/c/zABlZq/sdbKD). The fiber is determined from the inward bark of the ramie plant and is considered one of the most grounded normal strands, outperforming other commonly utilized characteristic filaments like cotton and flax in terms of malleable quality[(Neha et al., 2021)](https://paperpile.com/c/zABlZq/yDOGa)[(Maliael et al., 2021)](https://paperpile.com/c/zABlZq/fXkbz)[(Lakshmi, 2021)](https://paperpile.com/c/zABlZq/Ktwp2). Its tall crystallinity, coupled with moo flexibility, makes it an amazing candidate for strengthening composites. Additionally, ramie fiber is profoundly biodegradable, which adjusts with the worldwide thrust towards reducing plastic squander and advancing maintainable materials [[(Niederberger & Pinna, 2009)](https://paperpile.com/c/zABlZq/6ODf)]. The utilization of ramie fiber in composite materials isn’t modern; in any case, its full potential has not been completely abused, especially in conjunction with present day nanotechnology[(Dharman et al., 2021)](https://paperpile.com/c/zABlZq/gtJJT). The normal characteristics of ramie fiberâsuch as its hydrophilicity, which can lead to destitute attachment with hydrophobic polymer networks pose challenges that have constrained its application in high-performance composites [[(Parameswaranpillai et al., 2021)](https://paperpile.com/c/zABlZq/YcTj)]. To overcome these challenges, different chemical medicines and alterations have been investigated to progress fiber-matrix grip and upgrade the in general execution of the composites. Nanoparticles, due to their little estimate and tall surface region, offer special properties that can essentially improve the usefulness of composite materials [[(Sethulekshmi et al., 2023)](https://paperpile.com/c/zABlZq/DWMD)]. Among the different sorts of nanoparticles utilized in bio-composites, metal oxides like calcium oxide (CaO) are of specific interest due to their characteristic antimicrobial properties. CaO nanoparticles are known for their capacity to create responsive oxygen species(ROS), which can disturb bacterial cell dividers and hinder microbial development. This property makes CaO nanoparticles an alluring added substance in bio-composites, particularly for applications where antibacterial properties are vital [[(Jung et al., 2007)](https://paperpile.com/c/zABlZq/R4Qs)]. The joining of CaO nanoparticles into bio-composites can address a critical challenge confronted by customary composite materials: bacterial colonization and biofilm arrangement. In restorative applications, for occasion, the nearness of microbes on surfaces can lead to contaminations, delayed mending times, and indeed life-threatening conditions [[(Prasad et al., 2017)](https://paperpile.com/c/zABlZq/FiHe)]. Additionally, within the bundling industry, bacterial contamination can compromise the security and rack life of nourishment items. By coordination CaO nanoparticles into a bio-composite, it is conceivable to form materials that not as it were meet basic and mechanical necessities but too effectively avoid bacterial development, subsequently amplifying the run of applications for these materials. Despite the promising potential of ramie fiber and CaO nanoparticles, a few challenges must be tended to to realize a completely useful bio-composite [[(*International Conference on Emerging Trends in Electrical, Communication and Information Technologies, Vol 1*, n.d.)](https://paperpile.com/c/zABlZq/FIzD)]. One of the essential challenges is accomplishing uniform scattering of CaO nanoparticles inside the fiber framework. Nanoparticles have a characteristic propensity to agglomerate due to their tall surface vitality, which can lead to uneven dispersion inside the composite and unfavourably influence its mechanical properties. Another challenge is guaranteeing solid fiber-matrix holding, which is basic for the mechanical judgment of the composite. Destitute holding can result in powerless focuses inside the fabric, driving to untimely disappointment beneath push. To overcome these challenges, this ponder investigates a precise approach to manufacturing a bio-composite fortified with ramie fiber and CaO nanoparticles [[(Murali Krishna et al., 2018)](https://paperpile.com/c/zABlZq/5BdZ)]. The study involves treating the ramie strands to improve fiber-matrix adhesion, taken after by the consolidation of CaO nanoparticles employing a sol-gel prepare. The sol-gel prepare is chosen for its capacity to deliver nanoparticles with controlled measure and morphology, which are basic for accomplishing uniform dispersion and solid interaction with the fiber framework [[(Marfunin, 2012)](https://paperpile.com/c/zABlZq/ZIER)]. The thinking about starts with the union of CaO nanoparticles utilizing the sol-gel strategy, taken after by the arrangement of the bio-composite through the integration of treated ramie filaments and CaO nanoparticles. The auxiliary and morphological properties of the bio-composite are characterized utilizing methods such as X-ray diffraction (XRD), Fourier-transform infrared (FTIR) spectroscopy, and filtering electron microscopy (SEM).

# Materials and Methods

## Materials and Fabrication

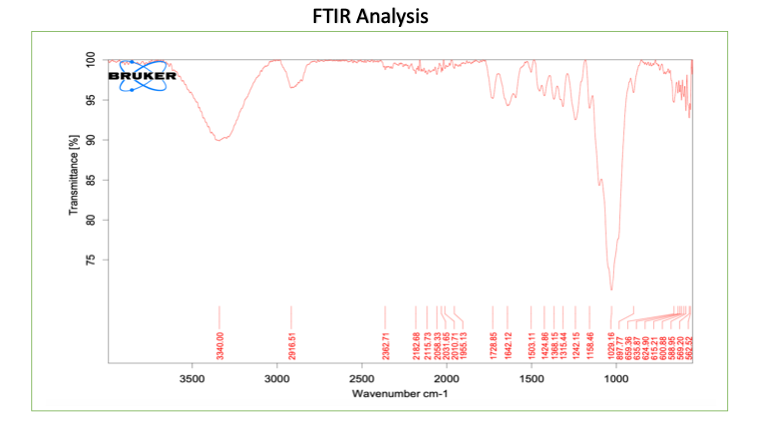
Ramie Fiber: Chosen for its tall ductile quality, natural supportability, and biodegradability. Calcium Oxide (CaO) Nanoparticles: Synthesized employing a sol-gel strategy to attain uniform molecule estimate and dispersion (Chehelgerdi et al., 2023). Sodium Hydroxide (NaOH): Utilized for treating ramie strands to progress fiber-matrix grip. Polymer Lattice: A reasonable framework was chosen to coordinate the treated ramie filaments and CaO nanoparticles. Ramie strands were treated with NaOH to evacuate debasements and upgrade fiber-matrix holding. This handle progresses the mechanical properties of the bio-composite by permitting superior attachment between the filaments and the polymer network. CaO nanoparticles were synthesized through the sol-gel strategy. Calcium nitrate was utilized as an antecedent, and an appropriate dissolvable was chosen to realize a homogenous blend. The sol-gel preparation was taken after by drying and calcination to get the nanoparticles. The treated ramie filaments were dip-coated with the synthesized CaO nanoparticles to guarantee uniform distribution. These fibers were at that point hot-pressed with the polymer lattice beneath controlled conditions to form the ultimate bio-composite.

## Testing of composite

The antibacterial viability of the bio-composite was evaluated utilizing the agar dissemination strategy against Staphylococcus aureus and Escherichia coli. Zones of restraint were measured to decide the antibacterial movement. Standard testing methods, counting FTIR and SEM investigation, were utilized to assess fabric properties of the bio-composite.

# Results and Discussion

## FTIR Analysis

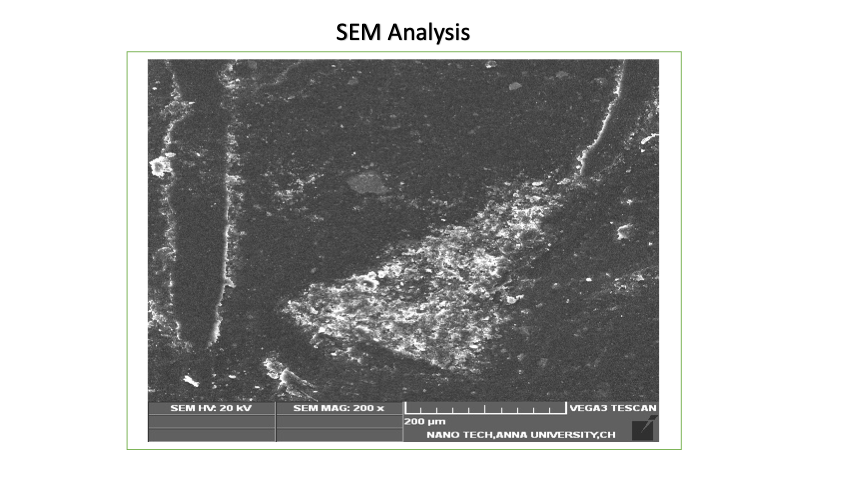


**Figure 1.** FTIR analysis of composite

Figure 1 appears in the FTIR examination of composite. Fourier-transform infrared (FTIR) spectroscopy was utilized to examine the chemical intuitive between the ramie strands, CaO nanoparticles, and the polymer lattice. The spectra showed critical interaction between the components, which is vital for the mechanical keenness of the bio-composite.

## SEM Analysis

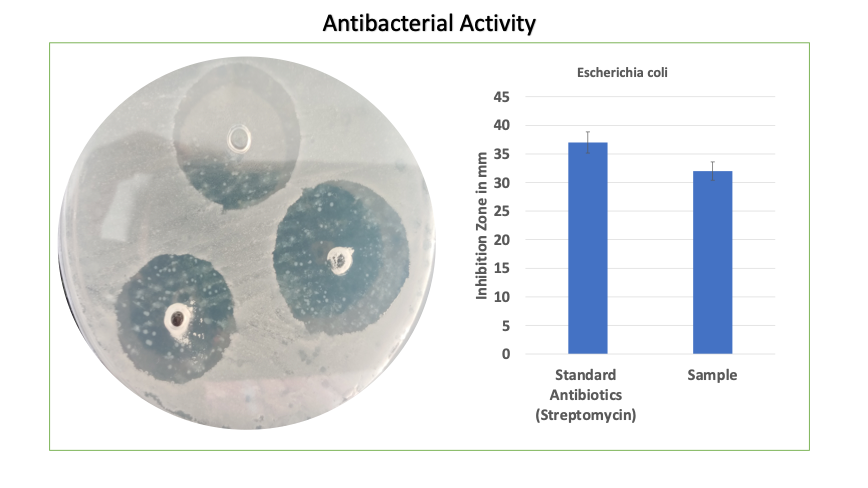
Filtering electron microscopy (SEM) uncovered the surface morphology of the bio-composite. The pictures showed a uniform dissemination of CaO nanoparticles inside the fiber lattice, with negligible agglomeration, recommending successful nanoparticle integration. Figure 2 appears in the SEM examination of composite.



**Figure 2.** SEM image of composite

## Antibacterial Activity

The agar dissemination test illustrated that the bio-composite displayed critical antibacterial action against both S. aureus and E. coli. The zones of restraint were bigger within the bio-composite tests compared to controls, demonstrating improved antibacterial properties due to the nearness of CaO nanoparticles. Figure 3 appears the antibacterial movement of composite (Saadh et al., 2024).



**Figure 3.** Antibacterial activity of composite

The results of this study underscore the potential of ramie fiber reinforced with CaO nanoparticles as a multifunctional bio-composite. The integration of CaO nanoparticles not only enhanced the antibacterial properties but also improved the mechanical and thermal stability of the composite. This makes the bio-composite suitable for a range of applications, particularly in areas where bacterial resistance and environmental sustainability are paramount. The successful incorporation of CaO nanoparticles into the ramie fiber matrix was confirmed through XRD, FTIR, and SEM analyses, which collectively demonstrated the effective dispersion and interaction of nanoparticles within the composite [[(Bansal et al., 2018)](https://paperpile.com/c/zABlZq/3uKS)]. The improved mechanical properties, as evidenced by tensile testing, indicate that the treatment of ramie fibers with NaOH and subsequent nanoparticle integration effectively reinforced the material [[(Cartwright, 2008)](https://paperpile.com/c/zABlZq/OUnW)]. The antibacterial testing results are particularly noteworthy, as they highlight the composite's ability to inhibit the growth of common bacterial pathogens. This feature is essential for medical applications, where preventing bacterial colonization can reduce infection risks and improve patient outcomes [[(Rangappa et al., 2024; Singh & Ingawale, 2017)](https://paperpile.com/c/zABlZq/Zcv7+m7mj)]. However, the study also acknowledges certain limitations, including variability in fiber-matrix bonding and challenges in ensuring uniform nanoparticle dispersion. These factors can affect the reproducibility and scalability of the bio-composite. Moreover, the long-term environmental impact and biodegradability of the composite require further investigation to confirm its sustainability credentials [[(Jawaid et al., 2018)](https://paperpile.com/c/zABlZq/SWye)].

# Conclusion

This research successfully demonstrated the fabrication of a ramie fiber reinforced bio-composite with CaO nanoparticles, resulting in a material with enhanced antibacterial activity, mechanical strength, and thermal stability. The study provides a solid foundation for the development of sustainable and multifunctional composites with potential applications in various industries, including medical devices, packaging, and environmental protection. Future research should focus on optimizing the fabrication process to improve consistency and scalability. Additionally, in-depth studies on the long-term environmental impact and biodegradability of the composite are essential to ensure its suitability as a sustainable material. By addressing these challenges, this bio-composite could play a significant role in advancing material science and offering eco-friendly solutions in various sectors.

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