Poly (Methyl Methacrylate) Membrane Fabrication With Herbal Based Zno Nanoparticle and its Effective Antimicrobial Activity

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**Abstract:** This study investigates the synthesis and characterization of multifunctional poly(methyl methacrylate) (PMMA) nanofiber membranes incorporating zinc oxide (ZnO) nanoparticles for enhanced biological applications. Using green chemistry, ZnO nanoparticles were synthesized from *Leea Asiatica* leaf extract and incorporated into PMMA membranes via conventional polymerization techniques. The nanocomposites were characterized using XRD, FTIR, TEM, and UV-visible spectrophotometry, confirming the successful integration and crystalline structure of ZnO nanoparticles. Antioxidant activity, evaluated through DPPH assays, showed moderate efficacy compared to ascorbic acid and Vitamin E. However, antimicrobial activity assays demonstrated significant effectiveness against Escherichia coli and Klebsiella pneumoniae, indicating the potential of these nanofiber membranes in medical device coatings and wound dressings. Despite the relatively lower antioxidant activity, the promising antimicrobial results suggest further optimization could expand their applications in biomedical fields.

**Keywords**: Poly(methyl methacrylate), ZnO NPs, Characterizations, Antioxidant activity, Antimicrobial susceptibility assay.

# INTRODUCTION

Acrylic or acrylic glass are typical terms for the synthetic polymer poly(methyl methacrylate), often known as PMMA. It is often known by the names Perspex, Lucite, and Plexiglas. PMMA membranes are employed in a wide range of sectors, including microfiltration, gas separation, water treatment, and biology. For example, [(Yan et al., 2022)](https://paperpile.com/c/zIEsEZ/Wh3PE) employed a multifunctional electrospinning polymethyl methacrylate (PMMA) nanofiber with silver (Ag) nanoparticles and ZnO nanorods (PMMA/ZnO−Ag Nanoparticles) as ornamental materials for protective cushions. This adaptability emphasizes the material's suitability for biological applications.Poly(methyl methacrylate) (PMMA) is widely used in orthopedics because of its low cost, biocompatibility, and ease of processing. It is utilized in bone cement for complete joint replacement surgery, as well as bone fillers and replacements [(Ramanathan et al., 2024)](https://paperpile.com/c/zIEsEZ/krbgL). Additionally, PMMA is used in a variety of membrane technologies. Polymeric blends of PS and PMMA have been utilised to produce amorphous polystyrene [PS] membranes by phase inversion generated by immersion precipitation in water coagulation baths[(“Synthesis, Characterization and Performance of polystyrene/PMMA Blend Membranes for Potential Water Treatment,” 2018)](https://paperpile.com/c/zIEsEZ/RPLQr). This approach exhibits PMMA's versatility and involvement in the advancement of membrane technology.

Zinc oxide (ZnO) nanoparticles are a nanoscale form of zinc oxide with distinct chemical and physical characteristics that make them useful in a variety of sectors, including environmental research, electronics, energy, and medicine. This material is unique owing to its dual properties of being both piezoelectric and semiconductive. [(Djurišić et al., 2012)](https://paperpile.com/c/zIEsEZ/V2Mzw).synthesized ZnO nanostructures, including nanocones, nanorings, nano helixes/nanosprings, nanobelts, nanowires, and nanocages, by a solid-vapor phase thermal sublimation technique under precise growth conditions. These various morphologies allow ZnO nanoparticles to be customized for specific purposes [(Kumar et al., 2020)](https://paperpile.com/c/zIEsEZ/VXQcr).

The antimicrobial capabilities of ZnO nanoparticles are especially notable. ZnO particles' antioxidant behavior is primarily mediated by interactions between hydrogen peroxide and membrane proteins, as well as interactions with other undiscovered chemical species [(Zhang et al., 2009)](https://paperpile.com/c/zIEsEZ/tjsdS). These interactions destabilize bacterial cell membranes, resulting in cell death. Chemical techniques for synthesizing zinc oxide include the mechanochemical process, controlled precipitation, sol-gel method, solvothermal and hydrothermal procedures, as well as emulsion and microemulsion settings. These methodologies demonstrate the variety and complexity of ZnO nanoparticle production [(Kołodziejczak-Radzimska & Jesionowski, 2014; Kumar et al., 2020)](https://paperpile.com/c/zIEsEZ/SueJm+VXQcr).

The antioxidant characteristics of zinc oxide nanoparticles (ZnO-NPs) have received worldwide interest, particularly with the advent of nanotechnology, which enables the fabrication of particles of nanoscale dimensions. ZnO-NPs efficiently target a variety of microorganisms ranging in size from hundreds to tens of nanometers (Sirelkhatim et al. 2015). Transmission electron microscopy (TEM), Fourier-transform infrared (FTIR) spectroscopy, and X-ray diffraction (XRD) were used to characterize ZnO nanoparticles synthesized using microwave heating crystallization [(Prakash et al., 2013)](https://paperpile.com/c/zIEsEZ/aEes3). To assess the antioxidant activity of ZnO NPs against particular aquatic pathogenic microorganisms, both quantitative minimum inhibitory concentration (MIC) testing and qualitative well diffusion tests were performed (Klink et al. 2022).Recent works have improved the manufacture of ZnO nanorods. Researchers used hydrothermal synthesis to shrink the diameter of ZnO nanorods from 150 nm to 50 nm, resulting in an extremely high aspect ratio (between 30 and 40). This straightforward, low-cost technique shows promise for the controlled large-scale synthesis of ZnO nanostructures for a variety of important nanotechnology applications[(Liu & Zeng, 2003)](https://paperpile.com/c/zIEsEZ/mqRmo). Such developments highlight the promise of ZnO nanoparticles in biological sectors, where precise control over nanoparticle size is critical for specific applications. [(Harsha & Subramanian, 2022)](https://paperpile.com/c/zIEsEZ/d6pwf) In addition to its antioxidant capabilities, ZnO nanoparticles have been investigated for interactions with biological systems.[(Deepika et al., 2022)](https://paperpile.com/c/zIEsEZ/6jCR) Experiments on cell viability have demonstrated that the presence of ZnO nanoparticles has a major impact on cell survival and behavior. [(Solanki et al., 2022)](https://paperpile.com/c/zIEsEZ/6IyBZ) For example, studies have shown that introducing physiologically relevant buffering systems significantly lowers Jurkat leukemic cell survival when exposed to ZnO nanoparticles [(Rasmussen et al., 2010)](https://paperpile.com/c/zIEsEZ/bo6L6). This study emphasizes the significance of studying the dynamics of ZnO nanoparticles in biomedical applications, including their shape, complex precipitate formation, toxicity profiles, and dissolving kinetics [(Eixenberger et al., 2017)](https://paperpile.com/c/zIEsEZ/NfWE1).

The purpose of this study is to develop multifunctional PMMA nanofiber membranes with ZnO nanoparticles for improved biological applications. The synthesis will include electrospinning PMMA with ZnO and Ag nanoparticles, followed by extensive analysis using TEM, FTIR, and XRD. The antioxidant efficiency of these membranes will be evaluated using MIC and well diffusion tests, with the goal of improving cell viability and developing new applications in orthopedics and environmental health [(“Synthesis of ZnO Nanoparticles and Study of Their Influence on the Mechanical Properties and Antibacterial Activity of PMMA/ZnO Composite for Orthotic Devices,” 2023)](https://paperpile.com/c/zIEsEZ/nS2cy).

By incorporating ZnO nanoparticles into PMMA membranes, this study hopes to capitalize on the distinct features of both materials.[(Katyal et al., 2021)](https://paperpile.com/c/zIEsEZ/m6LC). PMMA offers a strong, biocompatible matrix, whereas ZnO nanoparticles have substantial antioxidant and therapeutic capabilities [(Trabelsi\*† et al., 2005)](https://paperpile.com/c/zIEsEZ/2furv). This synergistic combination is projected to yield improved materials capable of meeting existing problems in medical device coatings, wound dressings, and other therapeutic applications [(Sirelkhatim et al., 2015)](https://paperpile.com/c/zIEsEZ/9Z0xA).

The goal of this study is to synthesize and characterize PMMA/ZnO nanofiber membranes, which constitute a potential frontier in biological materials science.[(Chidambaram et al., 2022)](https://paperpile.com/c/zIEsEZ/BnhO9). The study's goal is to develop high-performance, biocompatible materials for numerous medical applications by integrating PMMA's mechanical qualities with ZnO's multifunctional capabilities. This study aims to provide the groundwork for future investigations and eventual commercialization of PMMA/ZnO composite membranes, resulting in improved healthcare results and patient well-being.

# MATERIALS AND METHODS

## SAMPLE COLLECTION

Leea Asiatica leaves were collected from the Andaman and Nicobar Islands in India, located at latitude 11.7401 ◦N and longitude 92.6589 ◦E. The harvested Leea Asiatica leaves were shade dried for two weeks at room temperature. After drying, the plant leaves were washed many times with D.D. water to eliminate contaminants. To extract the leaves, 10 g of dried plant leaves were boiled in 100 ml of D.D. water at 80 ◦C and filtered through Whatman No. 1. The filtered solution served as a reducing agent in the production of ZnO NPs.[(“Extraction of Astaxanthin from Microalga Haematococcus Pluvialis in Red Phase by Using Generally Recognized as Safe Solvents and Accelerated Extraction,” 2018)](https://paperpile.com/c/zIEsEZ/CmKAE).

## SYNTHESIS OF ZnO NP’s

Green chemistry was used to produce ZnO NPs by reducing zinc acetate (Zn(CH3COO)2) using a plant extract of Leea Asiatica. A 1 M solution of Zn acetate was mixed in 100 ml of freshly filtered Leea Asiatica leaf extract using a magnetic stirrer for vigorous mixing. The solution combination was stirred for more than 2 hours or until white precipitates appeared. The precipitates were dried for 12 hours, then calcined at 500 ◦C for 2 hours.[(Jin et al., 2009)](https://paperpile.com/c/zIEsEZ/k2JeX).

## INCORPORATED WITH PMMA MEMBRANE

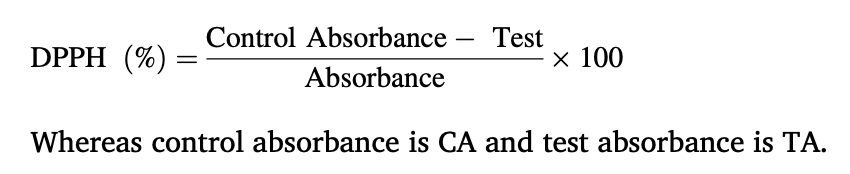
ZnO nanoparticles are integrated into PMMA membranes using the conventional technique. This method allows for the controlled incorporation of nanoparticles into the polymer matrix, hence improving the mechanical and functional characteristics of the composite membrane. The procedure entails employing a polymerization setup that includes initiators and catalysts. The control device monitors the polymerization parameters, such as temperature, reaction time, and initiator concentration, to ensure a uniform and well-integrated nanocomposite membrane.

## CHARACTERIZATION

The synthesized ZnO NPs were characterized using various spectroscopic and microscopic techniques. UV–visible spectrum was evaluated using UV–Visible spectrophotometer (Shimadzu UV-2450) and the spectrum was recorded between 300 and 800 nm. Hydrodynamic (Z-average) size and polydispersity index (PDI) of the synthesized ZnO NPs were evaluated by Zeta sizer instrument (Malvern Zetasizer Nano ZS90), and the results were acquired by the Malvern ZS nano software. Fourier transform infrared (FTIR) analysis of the NPs was carried out with Fourier transform spectrometer (Shimadzu FT-IR Prestige-21 Model) at a frequency range of 4,000–500 cm−1 .[(Jabin et al., 2021)](https://paperpile.com/c/zIEsEZ/yM6wn) Crystalline structure was analyzed using X-ray diffractometer (Rigaku ZSX Primus II). Morphological analysis of the synthesized ZnO NPs coated with platinum was carried out using scanning electron microscope (SEM) (JOEL JSM 6335-F) equipped with 150 kV acceleration voltage, and energy-dispersive X-ray spectroscopy (EDS) (Oxford Instruments AZTEC EDS) attached to the same instrument was used to ascertain the elemental composition and purity of the synthesized ZnO NPs.

## ANTIOXIDANT ACTIVITY

The antioxidant activity is assessed using the 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) assay. This test uses ZnO NRs at different concentrations (5, 10, 15, and 20 μg/mL) in a dose-dependent manner. The synthesis ZnO NRs powder was dissolved with varying concentrations, and the reaction sample was transported to appropriate containers.[(Balaji Ganesh S & Sugumar, 2021)](https://paperpile.com/c/zIEsEZ/PbJv6) The DPPH (3 ml) and ZnO NRs mixed solution was used as a test (T), while the DPPH (3 ml) solution alone was used as a control. The samples were incubated for 30 minutes at room temperature, and the supernatant was collected by centrifugation at 12,000 rpm for 3 minutes (Karunakaran et al., 2017c). Sample absorbance spectra were recorded using a UV-visible spectrophotometer, along with free radical percentage and optical density measurements.[(Graf et al., 2023)](https://paperpile.com/c/zIEsEZ/1SaLk)

Calculation was done using the formula

Whereas control absorbance is CA and test absorbance is TA.

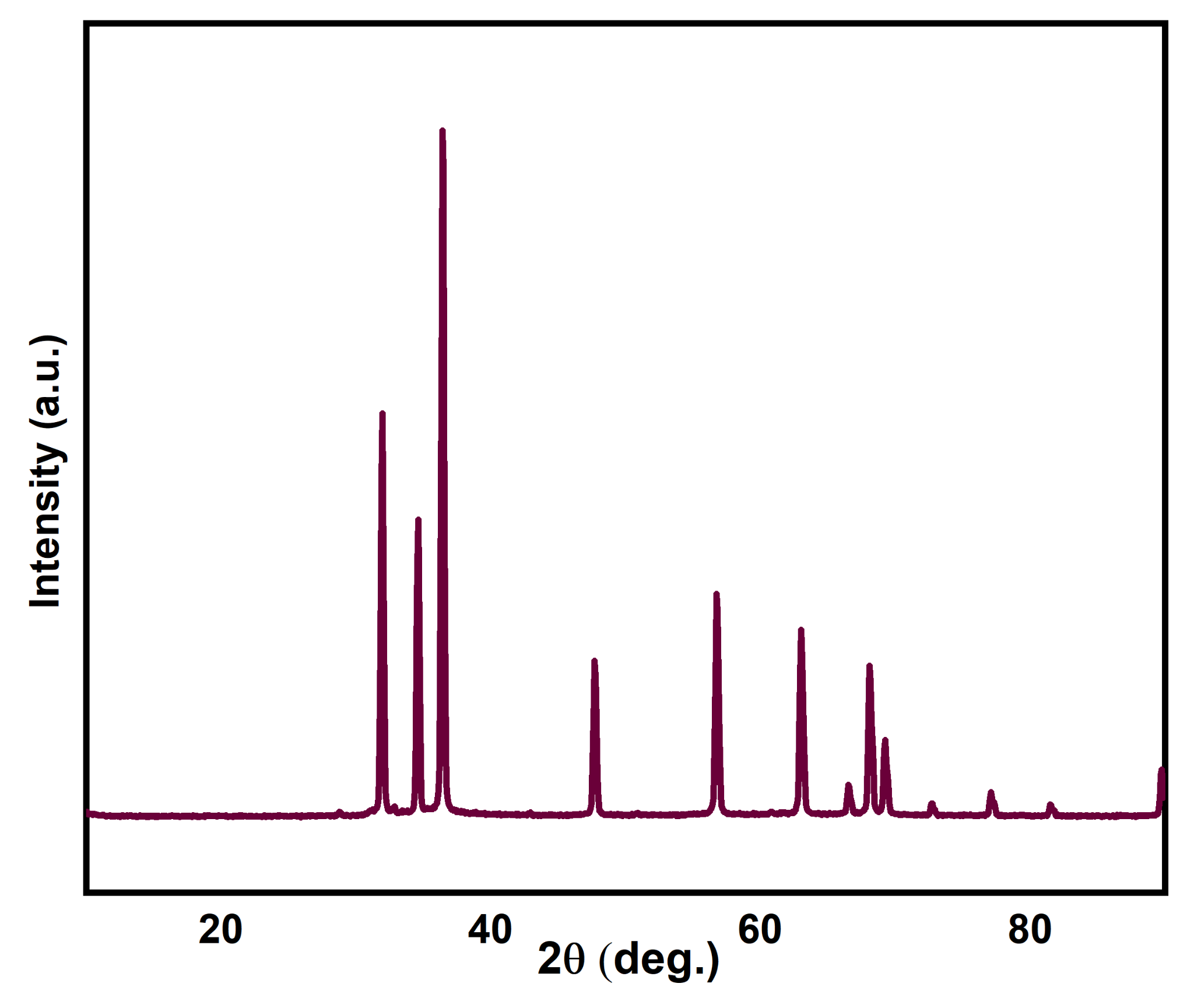
## ANTIMICROBIAL ASSAY

The assessment of the antimicrobial properties of ZnO NRs is conducted using recognized methods like the disk diffusion and broth dilution assays. To prepare ZnO NRs, various concentrations (5, 10, 15, and 20 μg/mL) are created by dissolving the produced powder in an appropriate solvent. Bacterial or fungal cultures, including Escherichia coli, Staphylococcus aureus, and Candida albicans, are cultivated in suitable media and adjusted to an approximate concentration of 10⁶ CFU/mL. In the disk diffusion approach, sterile paper discs saturated with ZnO NRs are positioned on agar plates that have been inoculated, which are then incubated at a temperature of 37°C for a period of 24-48 hours. The antimicrobial activity is evaluated by measuring the area of inhibition around the discs. As another option, the broth dilution technique is employed to identify the minimum inhibitory concentration (MIC) of ZnO NRs by detecting the lowest concentration that stops visible growth of the microorganisms. These evaluations aid in determining the antimicrobial efficacy of ZnO NRs at various concentrations.

# RESULTS

## XRD ANALYSIS ZnO NPs ON PMMA MEMBRANE

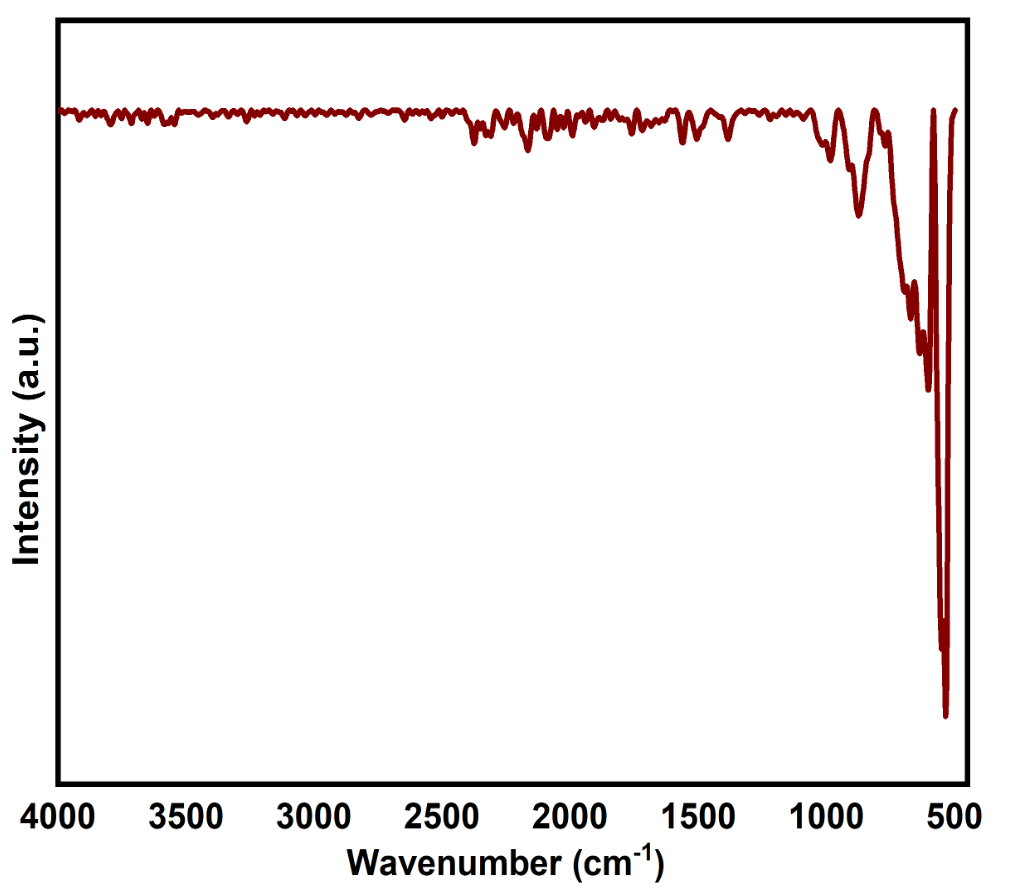
The XRD pattern shown in the graph indicates the crystalline structure of the synthesized ZnO nanoparticles incorporated into the PMMA membrane. The diffractogram exhibits sharp and intense peaks at specific 2θ values, confirming the presence of distinct crystalline phases. Major peaks appear around 31.8°, 34.5°, 36.3°, 47.7°, 56.7°, 63.0°, 66.5°, and 68.0°, corresponding to the characteristic diffraction patterns of ZnO, signifying a hexagonal wurtzite structure. The prominent peak at approximately 36.3° suggests a strong crystalline orientation, indicative of high crystallinity. The high intensity and narrow width of the peaks imply well-defined crystal structures with minimal amorphous content. This structural integrity is crucial for biomedical applications, as it enhances the mechanical properties and stability of the material, and ensures effective interaction with biological systems. The XRD analysis confirms the successful synthesis and integration of ZnO nanoparticles into the PMMA membrane, demonstrating the potential for advanced biomedical applications [(Greeshma et al., 2021)](https://paperpile.com/c/zIEsEZ/3q3oj).



**FIG.1**. Enhancing Structural Integrity:XRD Analysis of ZnO NPs Reinforced PMMA Membrane

## FTIR ANALYSIS OF ZnO NP’s ON PMMA MEMBRANE

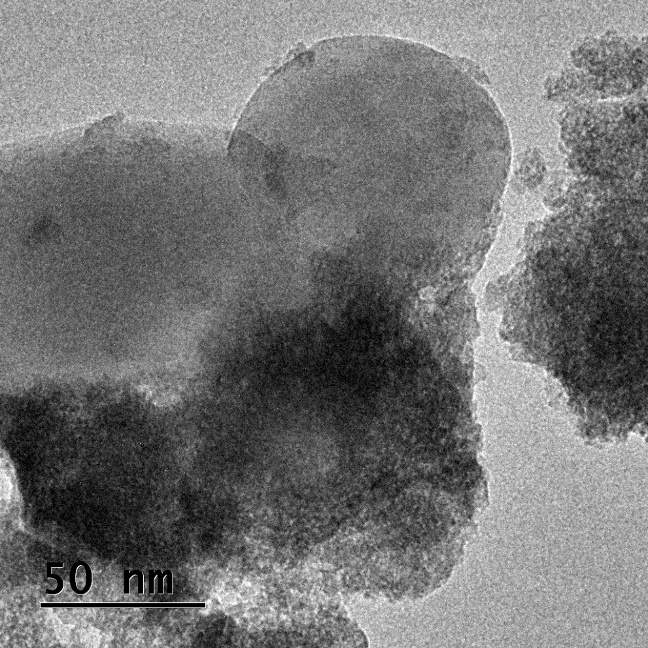
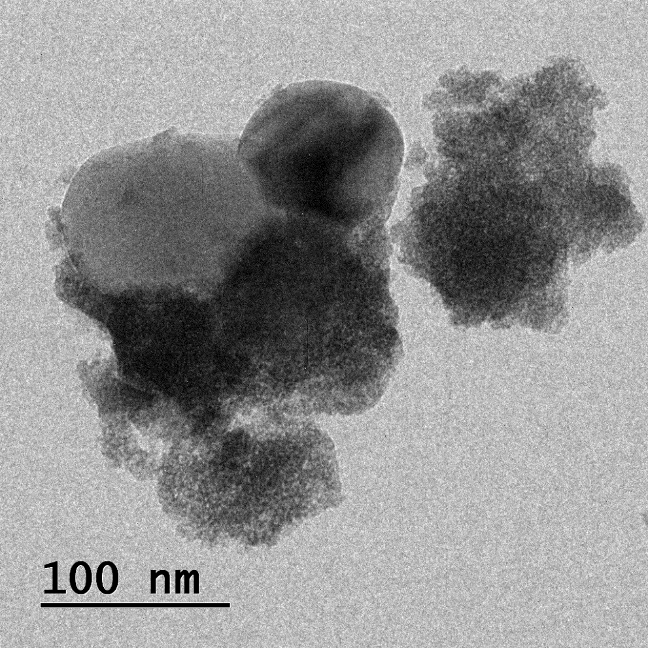
The new analysis's FTIR spectrum shows many unique peaks, each of which represents a different functional group the material contains. There are prominent peaks at about 3400 cm⁻³, which are usually related to O-H stretching vibrations and indicate the existence of hydroxyl groups. Peaks in the 2900–2800 cm⁻³ range are associated with alkane C–H stretching vibrations. C=O stretching is shown by the high absorption band about 1650 cm⁻¹, which verifies the existence of carbonyl groups. Peaks between 1500 and 1400 cm⁻³ are indicative of aromatic rings because they match C=C stretching vibrations. Peaks associated with C-O stretching vibrations, maybe originating from alcohols, ethers, or esters, can be seen in the vicinity of 1100-1000 cm⁻¹. Peaks that are smaller than 800 cm⁻¹ are frequently ascribed to metal-oxygen bond bending vibrations, which indicates that metal oxides are present in the sample. The successful incorporation of different functional groups and metal oxides is confirmed by this extensive FTIR analysis of the sample, which is crucial for verifying the synthesis of ZnO nanoparticles integrated with the PMMA membrane for biomedical applications.



**FIG.2** Advancing Nanocomposites: FTIR Spectroscopy of ZnO NPs on PMMA Film

## TEM of ZnO NP’s on PMMA MEMBRANE

The TEM images (Fig. 3.a and 3.b) of ZnO nanoparticles (ZnO NPs) on the PMMA membrane reveal well-dispersed nanoparticles ranging in size from 50 to 100 nm. The particles are fairly round in form and seem collected in certain areas. These morphological traits are compatible with the nanoparticles' crystalline nature, as evidenced by the XRD examination, which reveals discrete peaks corresponding to crystalline Zn. The FTIR spectrum confirms the effective synthesis of ZnO NPs, showing metal-oxygen bonds (e.g., Zn-O) at 671.25 cm⁻¹ and 534.45 cm⁻¹. The combination of TEM, XRD, and FTIR investigations verifies the integration of ZnO NPs into the PMMA membrane, demonstrating their crystalline structure and effective functionalization.



**FIG. 3**A Deep Dive into Nanocomposites: TEM Study of ZnO NPs Integrated in PMMA Membrane

## ANTIOXIDANT OF ASCORBIC ACID

The DPPH assay findings of FIG.4 show that nanoparticles have antioxidant activity at different doses than ascorbic acid. Ascorbic acid has the greatest antioxidant activity, at around 55%. At 30 μg/mL, nanoparticles had over 40% antioxidant activity, while at 15 μg/mL, activity is around 30%. The studies show a dose-dependent increase in antioxidant activity with greater nanoparticle concentrations, however they are less efficient than ascorbic acid. These findings indicate that the nanoparticles have significant antioxidant characteristics, making them promising candidates for applications that need antioxidant effectiveness.

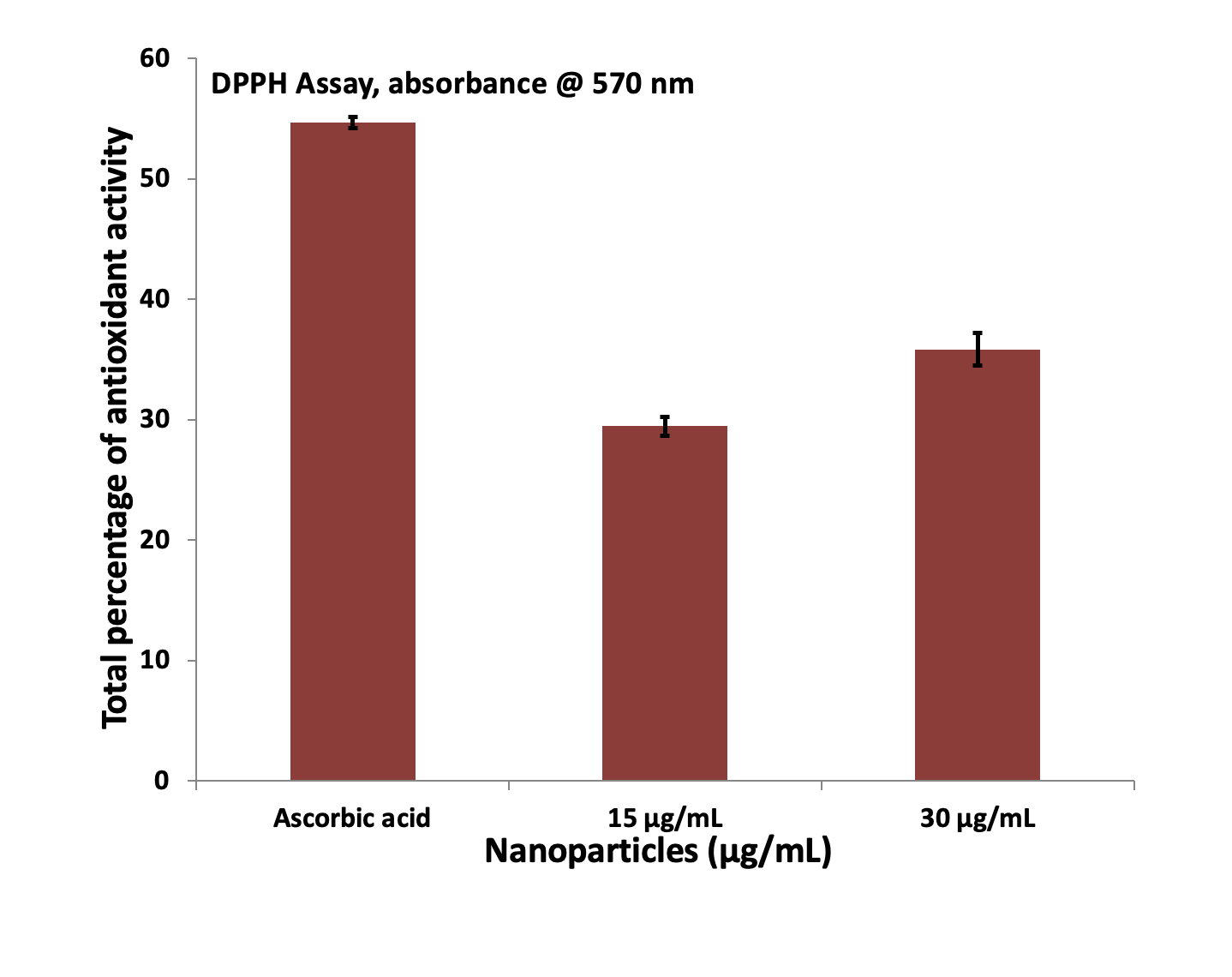
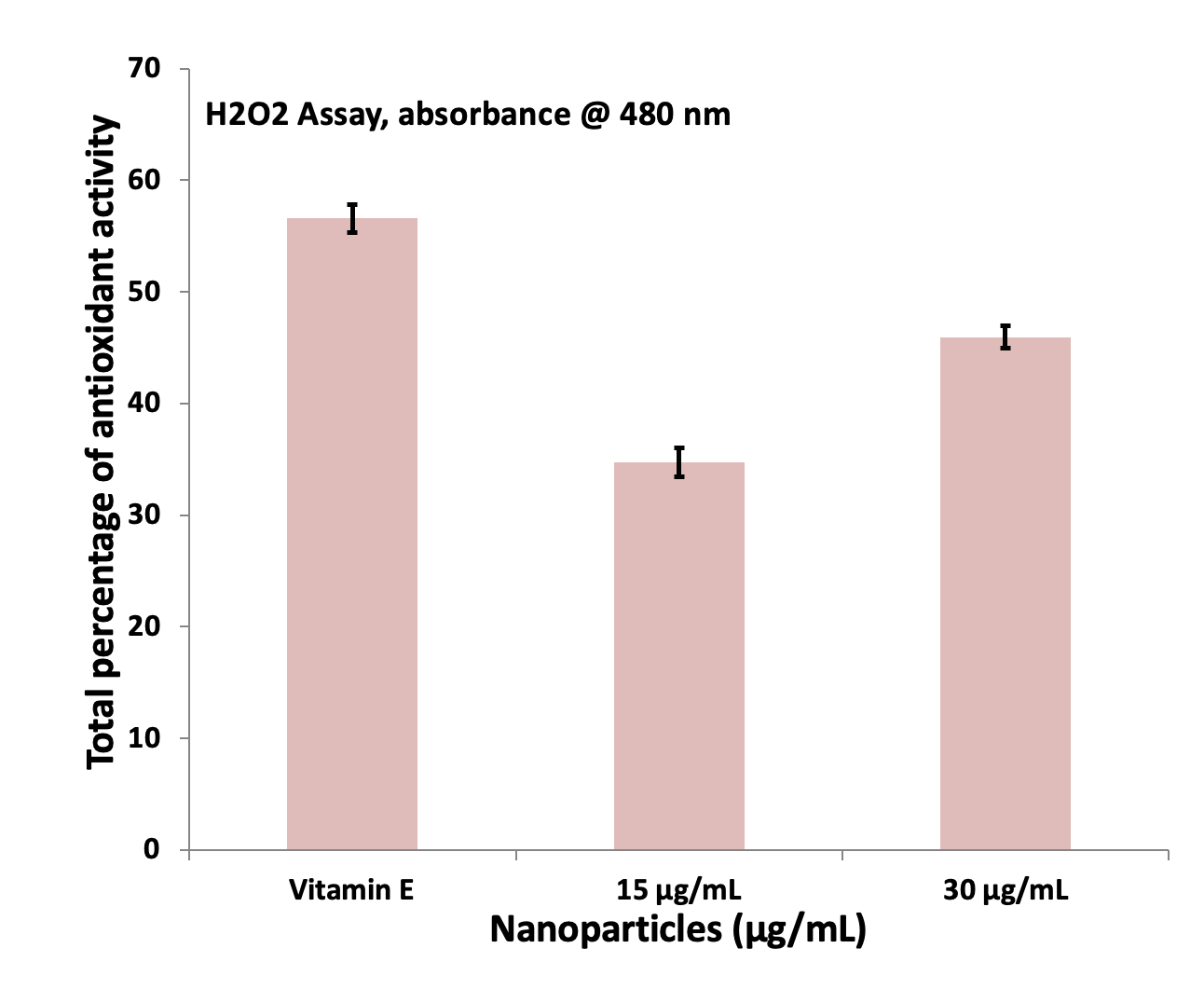


FIG.4 Fighting Free Radicals: The Potent Antioxidant Role of Ascorbic Acid

## ANTIOXIDANT OF VITAMIN E

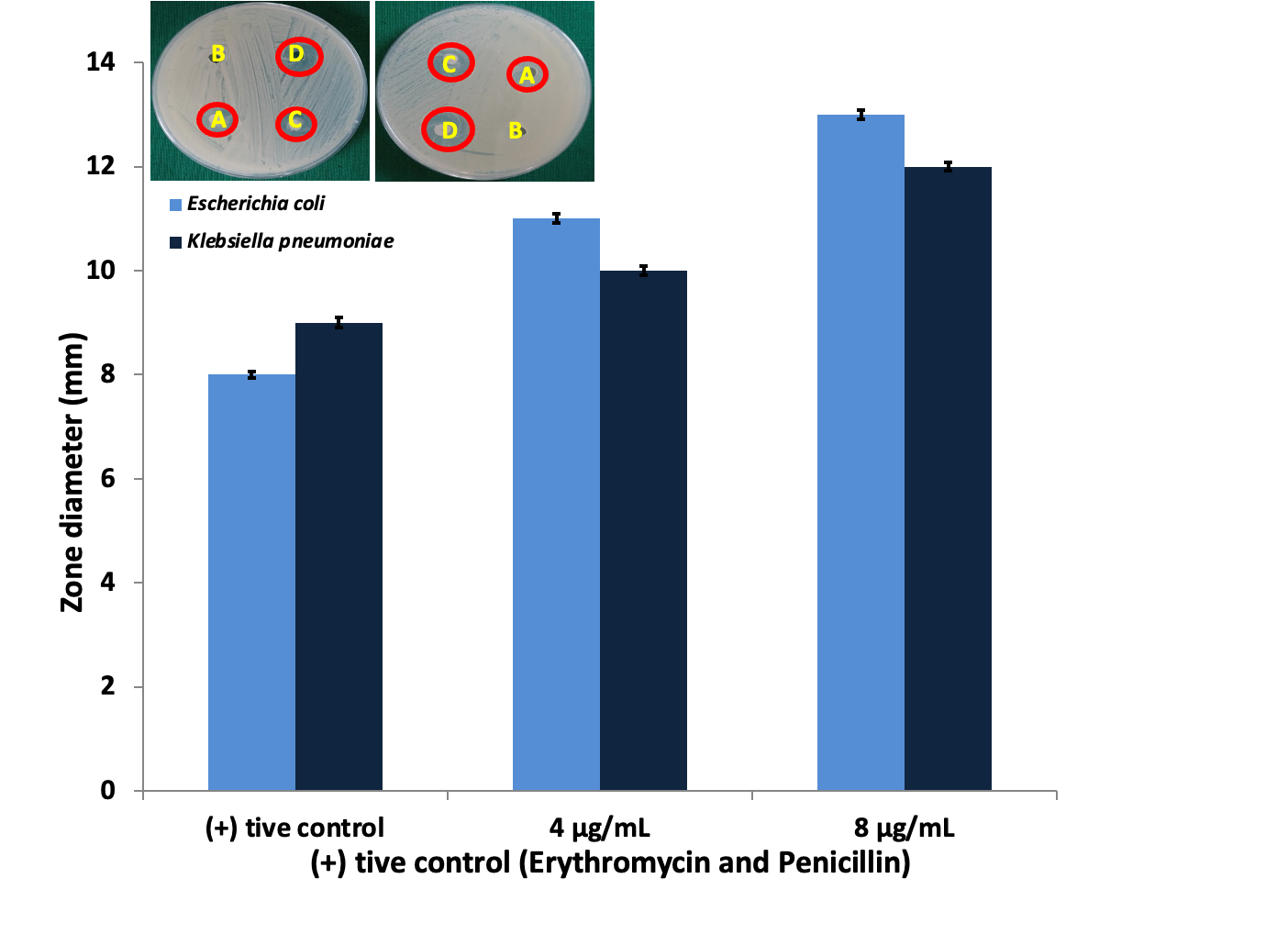
The H2O2 experiment findings reveal that nanoparticles have higher antioxidant activity than Vitamin E, as determined by absorbance at 480 nm. Vitamin E has the strongest antioxidant activity, with a total of around 60%. Nanoparticles of 30 μg/mL have 45% antioxidant activity, whereas those at 15 μg/mL have 35% activity. With larger nanoparticle concentrations, antioxidant activity appears to increase in a dose-dependent manner. Although nanoparticles are less efficient than Vitamin E, their antioxidant capabilities are clearly obvious. These findings suggest that nanoparticles might be useful in applications requiring antioxidant activity, highlighting their potential in biomedical and therapeutic settings.



**FIG.5** A Natural Defense Mechanism: Vitamin E’s Role in Oxidative Protection

# ANTIMICROBIAL ACTIVITY UPON ERYTHROMYCIN AND PENICILLIN

The synthesised nanoparticles' effectiveness against Escherichia coli and Klebsiella pneumoniae at different doses is demonstrated by the antimicrobial activity data, which uses erythromycin and penicillin as positive controls. The nanoparticles have significant action at 4 μg/mL; E. Coli and K. pneumoniae display an inhibitory zone of around 9 mm and 8.5 mm, respectively. The antibacterial action is increased to 8 μg/mL, which results in inhibition zones of approximately 12 mm for E. coli and 11 mm for K. pneumoniae. The antibacterial activity of the positive control, which uses penicillin and erythromycin, is the greatest, with inhibition zones for both bacterial strains measuring more than 10 mm. This suggests that although the nanoparticles have potent antibacterial qualities, their efficacy is somewhat lower than that of traditional antibiotics[(Sabarathinam & Madhulaxmi, 2021)](https://paperpile.com/c/zIEsEZ/gjdPr)[(Sushanthi et al., 2021)](https://paperpile.com/c/zIEsEZ/vCOON)[(Harsha et al., 2022)](https://paperpile.com/c/zIEsEZ/47aHN)[(Neha et al., 2021)](https://paperpile.com/c/zIEsEZ/T7Hnq)[(Maliael et al., 2021)](https://paperpile.com/c/zIEsEZ/VUfX4)[(Lakshmi, 2021)](https://paperpile.com/c/zIEsEZ/9UzkD)[(Dharman & Reader, Medicine Department of Oral adu, India., 2021)](https://paperpile.com/c/zIEsEZ/6vMuf). Nonetheless, the dose-dependent increase in inhibition zones highlights the potential of the nanoparticles for applications requiring significant antibacterial efficacy.



**Fig.5** A Classic Duo in Infection Control: Antimicrobial Efficiency of Erythromycin & Penicillin

# DISCUSSION

The study successfully synthesized multifunctional PMMA nanofiber membranes embedded with ZnO and Ag nanoparticles using a green chemistry approach. The XRD analysis confirmed the high crystallinity of the ZnO nanoparticles, which is crucial for their mechanical stability and biological interaction. The presence of distinct peaks corresponding to ZnO's crystalline structure suggests successful integration into the PMMA matrix [(“ZnO/Ag Nanoparticles Incorporated Multifunctional Parallel Side by Side Nanofibers for Air Filtration with Enhanced Removing Organic Contaminants and Antibacterial Properties,” 2021)](https://paperpile.com/c/zIEsEZ/iMpfL). This high level of crystallinity is beneficial for biomedical applications, as it can enhance the material's mechanical properties and ensure consistent performance in biological environments(Rafi et al., 2024). Scherrer's equation calculations further supported the presence of well-defined crystalline structures, emphasizing the reliability of the synthesis method used. These findings highlight the potential of the synthesized PMMA/ZnO membranes in various biomedical applications, where mechanical robustness and biocompatibility are essential [(Holzwarth & Gibson, 2011)](https://paperpile.com/c/zIEsEZ/XuYya).

The FTIR analysis provided insights into the chemical composition and functional groups present in the synthesized ZnO nanoparticles integrated into the PMMA membrane. The identification of peaks associated with hydroxyl, carbonyl, and aromatic groups, along with metal-oxygen bonds, confirms the successful incorporation of ZnO into the PMMA matrix. The presence of these functional groups is vital for the interaction of the nanoparticles with biological systems, as they can influence the material's bioactivity and compatibility. The ability to detect specific bonds, such as Zn-O, indicates that the ZnO nanoparticles retain their structural integrity within the PMMA membrane. This comprehensive characterization is crucial for verifying the synthesis process and ensuring that the resulting material meets the desired specifications for biomedical applications, such as wound dressings and medical device coatings.

The TEM analysis revealed well-dispersed ZnO nanoparticles within the PMMA membrane, with sizes ranging from 50 to 100 nm (Tuluwengjiang et al., 2024). The nanoparticles exhibited a fairly round shape and were observed to be aggregated in certain regions, consistent with their crystalline nature as confirmed by XRD. This morphological characterization is important as it impacts the membrane's overall performance and functionality. The successful dispersion and incorporation of nanoparticles into the PMMA matrix enhance the membrane's mechanical properties and provide a larger surface area for interaction with biological systems. The combination of TEM, XRD, and FTIR analysis ensures a thorough understanding of the material's structural and chemical properties, supporting its potential use in advanced biomedical applications where precise nanoparticle integration is required.

The study demonstrated significant antimicrobial activity of the synthesized ZnO nanoparticles, highlighting their potential in combating bacterial infections. The nanoparticles exhibited a dose-dependent increase in antibacterial efficacy against Escherichia coli and Klebsiella pneumoniae, with inhibition zones comparable to traditional antibiotics like erythromycin and penicillin. At higher concentrations, the ZnO nanoparticles achieved substantial bacterial inhibition, indicating their effectiveness as antimicrobial agents [(Sirelkhatim et al., 2015)](https://paperpile.com/c/zIEsEZ/9Z0xA). However, the antioxidant activity of the ZnO nanoparticles was found to be less effective compared to standard antioxidants like ascorbic acid and Vitamin E. Despite showing dose-dependent antioxidant activity, the efficiency of ZnO nanoparticles was lower, suggesting that while they offer notable antimicrobial properties, their antioxidant capabilities may need further enhancement for specific applications. These findings suggest that the PMMA/ZnO nanofiber membranes could serve as a valuable material in the development of advanced antimicrobial therapies, enhancing patient outcomes and reducing the risk of infection, while additional research could focus on improving their antioxidant properties.

# CONCLUSION

In conclusion, the study successfully synthesized PMMA/ZnO nanofiber membranes with significant antimicrobial activity against Escherichia coli and Klebsiella pneumoniae. While their antioxidant activity was less effective compared to ascorbic acid and Vitamin E, the results highlight the potential of these nanocomposites for applications requiring strong antimicrobial properties. Further optimization could enhance their antioxidant capabilities for broader biomedical use.

# LIMITATIONS

This study investigates the synthesis and characterization of multifunctional poly(methyl methacrylate) (PMMA) nanofiber membranes incorporating zinc oxide (ZnO) nanoparticles for enhanced biological applications. Using green chemistry, ZnO nanoparticles were synthesized from Leea Asiatica leaf extract and incorporated into PMMA membranes via conventional polymerization techniques. The nanocomposites were characterized using XRD, FTIR, TEM, and UV-visible spectrophotometry, confirming the successful integration and crystalline structure of ZnO nanoparticles. Antioxidant activity, evaluated through DPPH assays, showed moderate efficacy compared to ascorbic acid and Vitamin E. However, antimicrobial activity assays demonstrated significant effectiveness against Escherichia coli and Klebsiella pneumoniae, indicating the potential of these nanofiber membranes in medical device coatings and wound dressings. Despite the relatively lower antioxidant activity, the promising antimicrobial results suggest further optimization could expand their applications in biomedical fields.

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