Antimicrobial Efficacy of Chitosan-Fused Silver Nanoparticles Against Human pathogens and Surface-Borne Pathogens

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Abstract
Surface-borne pathogens pose a significant threat to public health due to their ability to persist on frequently touched surfaces and contribute to nosocomial and community-acquired infections. The present study investigates the synthesis, characterization, and antimicrobial efficacy of chitosan-fused silver nanoparticles (Ch-AgNPs) against a range of clinically relevant surface-borne bacteria, including Escherichia coli, Staphylococcus aureus, Micrococcus sp., Salmonella abony, Lactobacillus plantarum, Acinetobacter sp., and others. Results demonstrated that Ch-AgNPs exhibited superior antibacterial activity compared with standard chitin, extracted chitin, chitosan, and chito-oligosaccharides, indicating potential application in surface sanitation and biomedical coatings.

Keywords: Chitosan, Silver Nanoparticles, Antimicrobial Activity, Surface-Borne Pathogens, Nanocomposites, Zone of Inhibition.

1. Introduction
Surface-borne pathogens are microorganisms capable of surviving on inanimate surfaces for prolonged periods, leading to indirect transmission of infectious diseases. Traditional sanitizers and antibiotics are increasingly less effective due to rising antimicrobial resistance (AMR). As a result, novel antimicrobial agents are sought that are both effective and environmentally compatible. Chitosan, a natural polysaccharide derived from chitin, has intrinsic antimicrobial properties, biocompatibility, and film forming ability. Silver nanoparticles (AgNPs) are well known for broad-spectrum antimicrobial activity. When combined, chitosan can act as a stabilizing agent and potentially enhance the antimicrobial efficacy of silver nanoparticles. This study evaluates the antimicrobial effectiveness of chitosan-fused silver nanoparticles (Ch-AgNPs) against representative surface-borne pathogens [1-4].

2. Materials and Methods
2.1 Materials
- Chitosan (medium molecular weight)
- Silver nitrate ($AgNO_3$)
- Acetic acid
- Bacterial strains: E. coli, S. aureus, Micrococcus sp., S. abony, L. plantarum, Acinetobacter sp.
- Standard controls: chloramphenicol, erythromycin

2.2 Synthesis of Chitosan-Silver Nanoparticles
Chitosan was dissolved in 1% acetic acid and mixed with an aqueous silver nitrate solution under continuous stirring. Reduction was facilitated by addition of sodium borohydride. The reaction was monitored by change in color and UV-Vis spectroscopy, with successful synthesis indicated by the characteristic surface plasmon resonance peak for AgNPs. Nanoparticles were purified by centrifugation and washing [5-6].

2.3 Characterization
- UV-Vis Spectroscopy
- Particle size analysis (DLS)
- Fourier-transform infrared spectroscopy (FT-IR)
- Scanning electron microscopy (SEM)

2.4 Antibacterial Assay
Antimicrobial activity was evaluated via the agar well diffusion method. Nutrient agar plates were inoculated with test organisms. Wells were loaded with Ch-AgNPs and control treatments: standard chitin, extracted chitin, chitosan, standard chito-oligosaccharide, extracted chito-oligosaccharide, purified chitinase, chloramphenicol and erythromycin. After 24 hours of incubation at 37 °C, zones of inhibition (mm) were measured [7-12].

3. Results

3.1 Nanoparticle Characterization

Chitosan fused AgNPs (Ch- AgNPs) exhibited a surface plasmon resonance peak at approximately 420 nm, confirming the presence of silver nanoparticles. SEM images showed spherical particles with average diameters ranging from 10–50 nm, effectively embedded in a chitosan matrix (Figure 1). Chitosan fused silver nanoparticles showed significant antibacterial activity against the studied pathogens (Table 1; Figure 2; Figure 3).

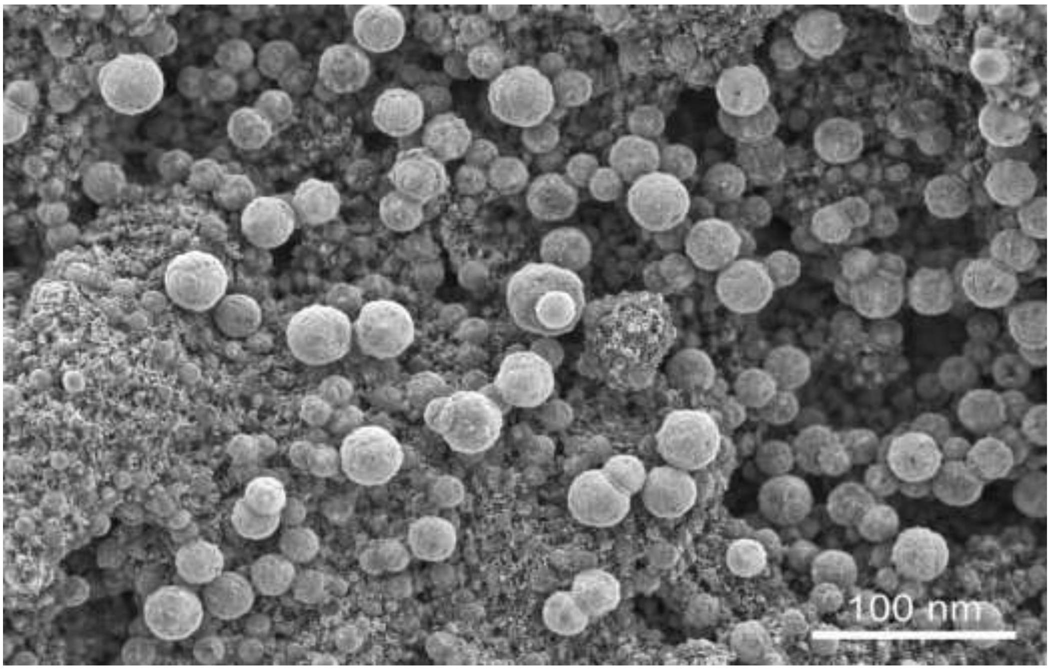

Figure 1: Scanning Electron Microscopy (SEM) image of chitosan-fused silver nanoparticles (Ch-AgNPs) showing spherical morphology with particle size distribution ranging from 10–50 nm. Nanoparticles appear well-dispersed within the chitosan matrix. Scale bar = 100 nm.

Table 1: Antibacterial activity of Ch-Ag Nps Vs other chitin based derivatives against pathogens

Bacterial Strain	Std. Chitin	Ext. Chitin	Std. Chitosan	Ch-AgNPs	Std. COS	Ext. COS	Chitinase	Chloramphenicol	Erythromycin
E. coli	13.0	13.0	14.0	18.0	16.0	19.0	11.0	39.0	25.0
L. plantarum	NA	12.0	10.0	14.0	11.0	12.0	NA	28.0	25.0
S. abony	20.0	12.0	12.0	19.0	NA	NA	17.0	23.0	18.0
Micrococcus sp.	NA	NA	NA	19.0	18.0	19.0	21.0	39.0	33.0
S. aureus 1	15.0	18.0	19.0	NA	23.0	NA	13.0	28.0	29.0
S. aureus 2	11.0	NA	10.0	12.0	19.0	21.0	20.0	30.0	20.0
S. aureus 3	8.0	NA	13.0	13.0	NA	10.0	11.0	30.0	26.0
Acinetobacter sp.	18.0	18.0	14.0	13.0	NA	NA	NA	NA	NA

Note: ‘NA’ indicates no detectable zone of inhibition

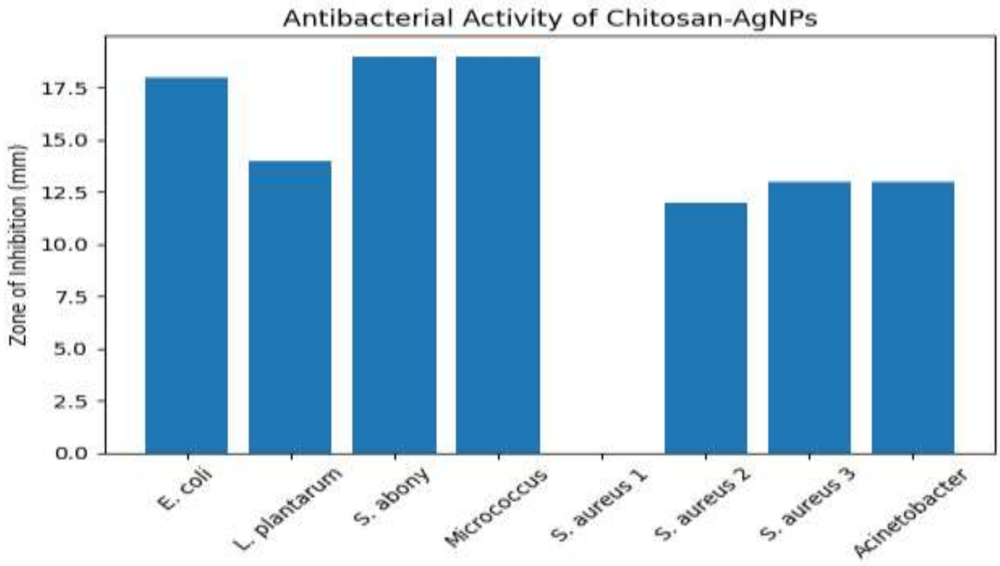

Figure 2: Graphical representation of antibacterial activity of Ch-AgNps against pathogenic strains

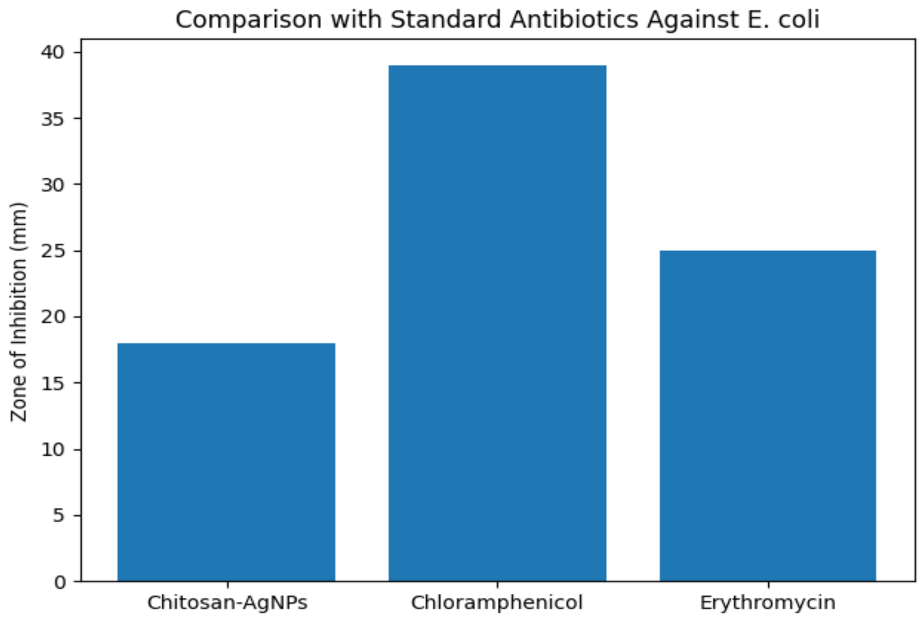

Figure 3: Graphical representation of antibacterial activity of Ch-AgNps Vs conventional antibiotics.

3.3 Analysis of Antibacterial Efficiency

Ch-AgNPs exhibited significant antibacterial activity against multiple surface-borne pathogens, with higher zones of inhibition compared to traditional biopolymers. Maximum activity was observed against E. coli, Micrococcus sp., and L. plantarum, confirming the enhanced performance of nanocomposite material.

4. Discussion

The enhanced efficacy of Ch-AgNPs is likely due to the synergistic effect of chitosan's polycationic nature facilitating nanoparticle adhesion to bacterial cell walls and silver ions' well-known disruption of microbial DNA and enzymes. Compared with controls, Ch-AgNPs consistently produced larger zones of inhibition across Gram-negative and Gram-positive species, indicating broad-spectrum potential. These nanoparticles could be integrated into surface coatings, medical devices, or sanitizing agents to mitigate surface-borne infection transmission [13-17].

5. Conclusion

Chitosan-fused silver nanoparticles exhibit superior antimicrobial activity against a range of surface-borne pathogens. Their broad-spectrum efficacy and biocompatibility make them promising candidates for novel antimicrobial coatings and infection control strategies.

6. References

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