

# Development And Characterization of Garlic (*Allium Sativum*) Extract-Loaded Biodegradable Nanoparticles For Targeted Antibacterial and Antiviral Therapy in Acute and Chronic Respiratory Infections

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## Abstract

**Background:** Respiratory infections, both acute and chronic, remain major global health burdens exacerbated by antimicrobial resistance and limited antiviral options. Garlic (*Allium sativum*) possesses broad-spectrum antimicrobial and antiviral activities but suffers from poor stability and bioavailability. Nanoparticle-based delivery systems can potentially enhance its therapeutic efficacy.

**Objective:** To develop and characterize biodegradable nanoparticles loaded with garlic extract for targeted antibacterial and antiviral therapy in respiratory infections, and to evaluate their cytotoxicity.

**Methods:** Garlic extract-loaded biodegradable nanoparticles were prepared using the solvent evaporation method and characterized for particle size, polydispersity index (PDI), zeta potential, morphology (SEM/TEM), encapsulation efficiency, drug loading, FTIR spectra, DSC/XRD profiles, and in vitro release in simulated lung fluid. Antibacterial activity was assessed using agar well diffusion, MIC/MBC determination, and time-kill kinetics. Antiviral potential was evaluated via plaque reduction assay, viral inhibition percentage calculation, and CPE inhibition assay. Cytotoxicity was tested on A549 cells using the MTT assay. Data were analyzed by one-way ANOVA with Tukey's post-hoc test ( $p < 0.05$ ).

**Results:** The optimized nanoparticles exhibited an average size of  $165 \pm 8$  nm, PDI of  $0.21 \pm 0.02$ , and zeta potential of  $-22.6 \pm 1.4$  mV, with encapsulation efficiency of  $82.4 \pm 2.3\%$  and drug loading of  $16.7 \pm 1.1\%$ . FTIR, DSC, and XRD confirmed successful encapsulation and reduced crystallinity. In vitro release showed sustained garlic bioactive release over 72 h. Nanoparticles displayed lower MIC/MBC values and larger inhibition zones compared to free garlic extract. Antiviral assays revealed  $>70\%$  plaque reduction and significant CPE inhibition. Cytotoxicity testing indicated  $>80\%$  cell viability at therapeutic concentrations, with a favorable selectivity index.

## Conclusion:

Garlic extract-loaded biodegradable nanoparticles enhanced antibacterial and antiviral efficacy with minimal cytotoxicity, suggesting their potential as a dual-action therapeutic platform for managing respiratory infections. Further in vivo and pharmacokinetic studies are recommended.

**Keywords:** *Allium sativum*, biodegradable nanoparticles, antibacterial activity, antiviral therapy, respiratory infections, cytotoxicity, drug delivery, phytomedicine.