

DEVELOPMENT AND CHARACTERIZATION OF *MYRISTICA FRAGRANS*-LOADED SILVER NANOPARTICLES (AGNPS) FOR ENHANCED ANTIMICROBIAL EFFICACY AGAINST MEAT-BORNE PATHOGENS

¹Zaryab Shafi, ²Suhail Ahmad, ³Mohammad Shahid, ⁴Rahul Singh

¹Research Scholar, Department of Biosciences, Integral University, Lucknow, U.P- 226026, India

²Research Scholar, Department of Bioengineering, Integral University, Lucknow, U.P- 226026, India

³Post doc fellow, ICAR-National Bureau of Agriculturally Important Microorganisms, Maunath Bhanjan, U.P- 275103, India

⁴Assistant Professor, Department of Bioengineering, Integral University, Lucknow, U.P- 226026, India

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Abstract. *Objective:* The primary objective of this study is to develop and characterize *M. fragrans*-loaded silver nanoparticles for enhanced antimicrobial efficacy against common meat-borne pathogens. Specifically, the study aims to reduce the required concentration of silver nanoparticles while maintaining or improving antibacterial activity, ultimately providing a safer, natural-based food preservation method.

Methodology: AgNPs will be synthesized and loaded with phyto-extract of *M. fragrans*. Characterization of the nanoparticles will be performed using UV-Vis spectroscopy, Dynamic Light Scattering (DLS), and Scanning Electron Microscopy (SEM). Antibacterial efficacy will be evaluated against common meat-borne pathogens, including *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* spp., with tests conducted in both in vitro and real food matrices.

Hypothesis: It is hypothesized that the combination of AgNPs with *M. fragrans* phyto-extract will enhance antimicrobial activity against meat-borne bacteria. This synergistic interaction will reduce the minimum inhibitory concentration (MIC) required, improving bacterial inhibition while reducing the potential toxicity of silver.

Conclusion: This study proposes a novel, natural-based preservation method using *M. fragrans*-loaded AgNPs to combat bacterial contamination in meat. The combination promises enhanced efficacy, reduced silver toxicity, and offers a sustainable solution to improving food safety and addressing antimicrobial resistance.

Introduction

Foodborne diseases remain a global public health challenge, with bacterial contamination in meat products being one of the major contributors [1]. Meat is highly susceptible to microbial contamination, particularly from pathogens like *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* spp., which pose serious health risks if not effectively controlled [2]. Traditional preservation methods, including chemical preservatives and refrigeration, have helped to mitigate this risk but are not fool proof [3]. Moreover, concerns over synthetic preservatives and the emergence of antibiotic-resistant bacteria have driven the need for more natural and effective preservation techniques [4].

Nanotechnology has emerged as a promising tool in food preservation, with silver nanoparticles (AgNPs) gaining considerable attention due to their strong antimicrobial properties. AgNPs have been shown to effectively kill a wide range of bacteria by interacting with bacterial cell membranes, disrupting cell function, and releasing silver ions that are toxic to microorganisms [5]. Despite these advantages, the use of AgNPs in food systems is often limited by concerns over their potential toxicity and environmental impact, particularly when used at high concentrations [6].

To address these limitations, recent research has explored the possibility of combining AgNPs with natural antimicrobial agents to enhance their efficacy while reducing the required dose of silver [7]. One such agent is *Myristica fragrans* (nutmeg), a spice known for its bioactive compounds, including phenolic compounds, terpenes, and alkaloids, which have demonstrated significant antibacterial activity [8]. By incorporating *M. fragrans* phyto-extract into AgNPs, this study aims to create a synergistic system that enhances the antimicrobial action of silver while mitigating its toxicity [9]. This novel approach could provide a natural, safe, and effective alternative for meat preservation, addressing consumer demand for eco-friendly food safety solutions.

Methodology

Synthesis of Silver Nanoparticles: Silver nanoparticles will be synthesized using a chemical reduction method. Silver nitrate (AgNO_3) will be used as the precursor, and sodium borohydride (NaBH_4) as the reducing agent. To ensure the stability of the nanoparticles, the synthesis will be conducted at controlled temperatures and pH levels. The reaction will be monitored by UV-Vis spectroscopy to confirm the formation of AgNPs through the appearance of a characteristic surface plasmon resonance (SPR) peak.

Preparation of *Myristica fragrans* Phyto-extract: The *M. fragrans* phyto-extract will be prepared by drying and pulverizing nutmeg seeds, followed by extraction with ethanol using a Soxhlet apparatus. The extract will be concentrated under reduced pressure and stored at low temperature until further use. The bioactive compounds, such as phenolic compounds, terpenes, and alkaloids, will be identified using gas chromatography-mass spectrometry (GC-MS).

Loading Phyto-extract into Silver Nanoparticles: The prepared *M. fragrans* phyto-extract will be incorporated into the AgNPs by adding the extract to the silver nitrate solution prior to the reduction step. The bioactive compounds in the extract are expected to act as both stabilizing and capping agents for the nanoparticles, leading to enhanced antibacterial properties. The successful loading of the extract will be confirmed by comparing the UV-Vis spectra of the phyto-extract-loaded AgNPs with those of plain AgNPs.

Characterization of Nanoparticles

UV-Vis Spectroscopy: The formation and stability of the AgNPs and phyto-extract-loaded AgNPs will be monitored using UV-Vis spectroscopy. The surface plasmon resonance (SPR) peak of AgNPs typically appears around 400-450 nm, and any shifts in this peak will indicate changes in nanoparticle size or composition.

Dynamic Light Scattering (DLS): DLS will be used to measure the size distribution and polydispersity index (PDI) of the nanoparticles in solution. A smaller and more uniform size distribution is expected for the phytoextract-loaded nanoparticles, which is crucial for enhanced antibacterial activity.

Scanning Electron Microscopy (SEM): SEM will be used to visualize the morphology and surface structure of the nanoparticles. The incorporation of *M. fragrans* phytoextract is hypothesized to result in more uniformly shaped and dispersed nanoparticles.

Antibacterial Testing: The antibacterial efficacy of the synthesized nanoparticles will be tested against *E. coli*, *S. aureus*, and *Salmonella* spp. using standard broth microdilution methods to determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC). Tests will be conducted in vitro and in real food matrices (meat samples) to evaluate the practical application of the nanoparticles in food preservation.

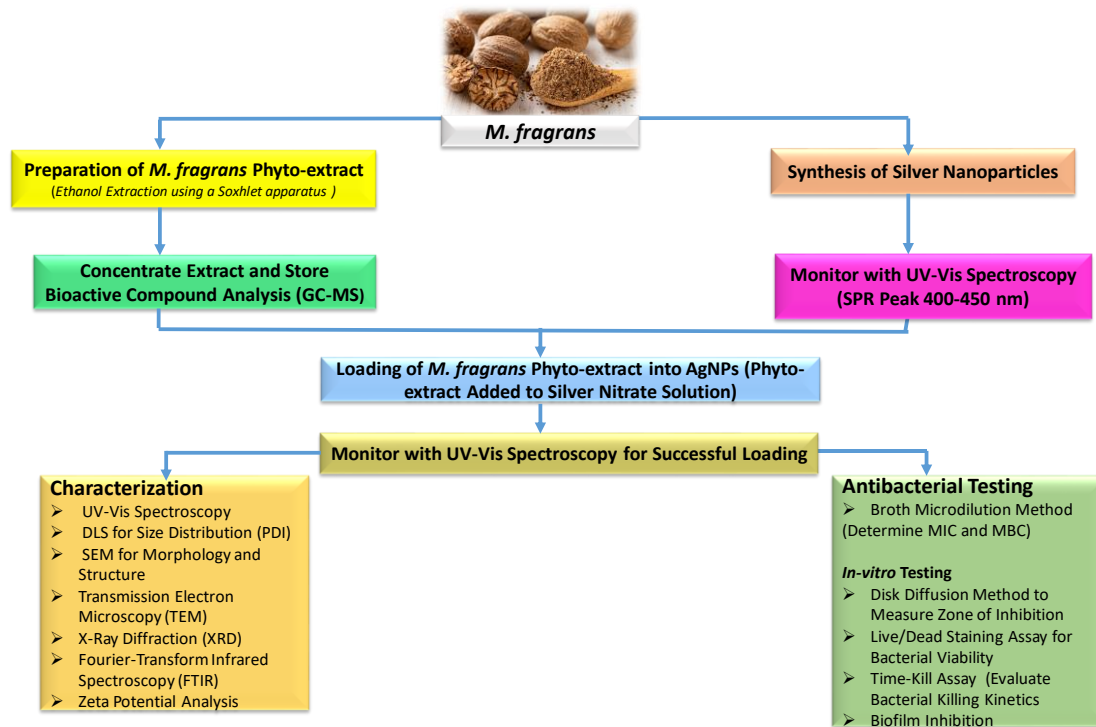


Fig 1: Methodology for the Synthesis, Characterization, and Antibacterial Testing of *Myristica fragrans*-Loaded Silver Nanoparticles (AgNPs)

Hypothesis

It is hypothesized that the combination of AgNPs with *M. fragrans* phytoextract will enhance antimicrobial activity against meat-borne bacteria. This synergistic interaction is expected to reduce the minimum inhibitory concentration (MIC) required to achieve bacterial inhibition, making the system more effective at lower concentrations of silver, thereby reducing the potential for toxicity. The bioactive compounds in *M. fragrans* are also expected to stabilize the nanoparticles, increase bacterial membrane permeability, and enhance the overall antimicrobial effect compared to AgNPs or phytoextract alone.

Conclusion

The development of *M. fragrans*-loaded silver nanoparticles presents a promising solution to the challenges of bacterial contamination in meat products. By combining the well-established antimicrobial properties of AgNPs with the bioactive compounds in *M. fragrans*, this study aims to create a natural, effective, and safer food preservation method. The incorporation of the phytoextract into the nanoparticles is expected to not only enhance the antimicrobial efficacy of AgNPs but also reduce the concentration of silver required, thereby mitigating toxicity concerns. This innovative approach holds great potential for improving food safety and shelf life while

addressing the growing concern of antimicrobial resistance. By leveraging the synergistic action between silver nanoparticles and *M. fragrans*, this study could pave the way for the development of natural-based nanoparticle systems for a wide range of applications in the food industry. Further experimental validation of this hypothesis through both in vitro and in situ testing will provide critical insights into the potential of this nanotechnology-based solution for real-world meat preservation applications.

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