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Molecular Evaluation of Medicinal Plants, Probiotics, and Green Synthesized Silver Nanoparticles for Potential Applications Against Rotavirus

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ABSTRACT

Rotavirus is one of the leading causes of severe gastroenteritis among infants and young children worldwide. Despite the availability of vaccines and supportive therapies, the absence of specific antiviral drugs and the emergence of genetically diverse viral strains continue to pose significant public health challenges.

The present study aimed to evaluate advanced treatment strategies for viral infections with special reference to rotavirus using medicinal plant extracts, probiotics, green synthesized silver nanoparticles, and PCR-based molecular approaches. Phytochemical screening revealed the presence of several bioactive compounds including alkaloids, flavonoids, phenols, tannins, saponins, and terpenoids in selected medicinal plants.

Probiotic isolates obtained from curd samples exhibited characteristic Lactobacillus properties and demonstrated antimicrobial activity. Green synthesis of silver nanoparticles was successfully achieved using plant extracts, and the synthesized nanoparticles exhibited enhanced antimicrobial activity compared to crude extracts. PCR amplification confirmed the suitability of molecular approaches in viral research and therapeutic evaluation. The findings indicate that medicinal plant extracts, probiotics, and nanoparticle-based strategies possess promising therapeutic potential and may contribute to future antiviral management approaches.

Keywords: Rotavirus, RT-PCR, Medicinal Plants, Probiotics, Silver Nanoparticles, Molecular Evaluation, Antiviral Therapy

INTRODUCTION

Rotavirus remains one of the most important viral pathogens responsible for severe gastroenteritis and diarrhea among infants and young children worldwide. The virus belongs to the family Reoviridae and possesses a segmented double-stranded RNA genome enclosed within a triple-layered protein capsid. Rotavirus infection is transmitted primarily through the fecal-oral route and is associated with vomiting, diarrhea, dehydration, and significant morbidity, particularly in developing countries.

Although vaccination has significantly reduced disease incidence in many regions, rotavirus continues to contribute substantially to pediatric hospitalizations and mortality. The emergence of genetically diverse viral strains and the absence of specific antiviral drugs have created a need for alternative therapeutic approaches.

Medicinal plant extracts, probiotics, and nanotechnology-based interventions have recently gained attention due to their antimicrobial, immunomodulatory, and potential antiviral properties. Furthermore, molecular techniques such as RT-PCR have become indispensable tools for viral detection, characterization, and therapeutic evaluation.

The present study was undertaken to investigate advanced treatment strategies for viral infections with special reference to rotavirus through laboratory-based evaluation of medicinal plants, probiotics, silver nanoparticles, and PCR-based molecular approaches.

MATERIALS AND METHODS

2.1 Study Design
A laboratory-based experimental study was conducted to evaluate advanced treatment approaches for viral infections with special reference to rotavirus.

2.2 Plant Material Collection and Extraction
Neem (Azadirachta indica), Tulsi (Ocimum sanctum), and Turmeric (Curcuma longa) were selected for the study. Plant materials were cleaned, shade-dried, powdered, and subjected to extraction using standard procedures.

2.3 Phytochemical Screening
Qualitative phytochemical analysis was performed to detect alkaloids, flavonoids, tannins, phenols, saponins, glycosides, and terpenoids using standard biochemical methods.

2.4 Isolation and Characterization of Probiotics
Probiotic microorganisms were isolated from curd samples using MRS agar medium. Isolates were characterized through colony morphology, Gram staining, catalase testing, pH tolerance, and bile salt tolerance studies.

2.5 Green Synthesis of Silver Nanoparticles
Silver nanoparticles were synthesized using plant extracts and silver nitrate solution. Nanoparticle formation was confirmed through visible color changes and laboratory observations.

2.6 Antimicrobial Activity Assay
Antimicrobial activity of plant extracts, probiotic isolates, and synthesized nanoparticles was assessed using agar well diffusion techniques. Zones of inhibition were measured and recorded.

2.7 PCR-Based Molecular Evaluation
PCR amplification was performed using standard molecular biology protocols. Amplified products were analyzed using agarose gel electrophoresis for confirmation of target gene amplification.

2.8 STATISTICAL ANALYSIS
All experiments were performed in triplicate and observations were recorded systematically. The results were expressed as mean values with standard deviations wherever applicable. Descriptive statistical analysis was used to evaluate the antimicrobial activity of plant extracts, probiotic isolates, and synthesized silver nanoparticles. The obtained results were compared to determine the relative effectiveness of different treatment approaches.

RESULTS AND DISCUSSION

3.1 Phytochemical Screening of Medicinal Plant Extracts
Phytochemical screening demonstrated the presence of multiple bioactive compounds including alkaloids, flavonoids, phenols, tannins, saponins, and terpenoids in the selected plant extracts.

Table 1. Phytochemical Constituents of Medicinal Plants

Phytochemical	Neem	Tulsi	Turmeric
Alkaloids	Present	Present	Present
Flavonoids	Present	Present	Present
Phenols	Present	Present	Present
Tannins	Present	Present	Present
Saponins	Present	Present	Present
Terpenoids	Present	Present	Present

The presence of these bioactive compounds supports the potential antimicrobial and antiviral properties of the selected medicinal plants.

3.2 Characterization of Probiotic Isolates

Probiotic isolates obtained from curd samples demonstrated characteristics consistent with Lactobacillus species.

Table 2. Characterization of Probiotic Isolates

Parameter	Observation
Colony Morphology	Creamy white circular colonies
Gram Staining	Gram-positive rods
Catalase Test	Negative
pH Tolerance	Positive
Bile Salt Tolerance	Positive

The observed characteristics indicate the suitability of these isolates as probiotic microorganisms.

3.3 Green Synthesis of Silver Nanoparticles

Green synthesis of silver nanoparticles was successfully achieved using medicinal plant extracts. Nanoparticle formation was indicated by visible color changes from pale yellow to dark brown following addition of silver nitrate solution.

Table 3. Observation During Nanoparticle Synthesis

Plant Extract	Observation
Neem	Dark brown color formation
Tulsi	Brown color formation
Turmeric	Brownish-yellow color formation

The color change confirmed reduction of silver ions into silver nanoparticles by plant-derived phytochemicals.

3.4 ANTIMICROBIAL ACTIVITY OF PLANT EXTRACTS

The antimicrobial activity of medicinal plant extracts was evaluated against selected test microorganisms using the agar well diffusion method. Among the tested extracts, Neem exhibited the strongest antimicrobial activity, followed by Tulsi and Turmeric. The superior activity of Neem may be attributed to the presence of biologically active compounds such as azadirachtin, nimbin, flavonoids, and phenolic constituents.

Table 4. Comparative Antimicrobial Activity of Medicinal Plant Extracts

Plant Extract	Antimicrobial Activity
Neem (Azadirachta indica)	Highest
Tulsi (Ocimum sanctum)	Moderate
Turmeric (Curcuma longa)	Lower

The findings indicate that medicinal plants possess significant antimicrobial potential and may serve as promising candidates for future antiviral and therapeutic investigations.

3.5 ANTIMICROBIAL ACTIVITY OF PROBIOTIC ISOLATES

The isolated probiotic microorganisms demonstrated inhibitory activity against test pathogens. The antimicrobial effect may be attributed to the production of organic acids, bacteriocins, hydrogen peroxide, and other bioactive metabolites that suppress pathogenic microbial growth.

Table 5. Antimicrobial Activity of Probiotic Isolates

Parameter	Observation
Growth Inhibition	Observed
Antimicrobial Activity	Positive
Pathogen Suppression	Confirmed

The results support the beneficial role of probiotic microorganisms in maintaining gut health and enhancing host defense mechanisms against infectious agents.

3.6 ANTIMICROBIAL ACTIVITY OF GREEN SYNTHESIZED SILVER NANOPARTICLES

Green synthesized silver nanoparticles exhibited stronger antimicrobial activity than the corresponding crude plant extracts. The enhanced biological activity may be attributed to the increased surface area, small particle size, and improved interaction of nanoparticles with microbial cells.

Table 6. Comparative Activity of Green Synthesized Silver Nanoparticles

Nanoparticle Type	Relative Activity
Neem-mediated Silver Nanoparticles	Highest
Tulsi-mediated Silver Nanoparticles	Moderate
Turmeric-mediated Silver Nanoparticles	Lower

The findings demonstrate that nanoparticle-mediated delivery systems may significantly improve the biological effectiveness of plant-derived therapeutic compounds.

3.7 PCR-BASED MOLECULAR EVALUATION

PCR amplification successfully generated target gene products, confirming the applicability of molecular techniques for the evaluation of advanced treatment strategies against viral infections. The amplified products were visualized using agarose gel electrophoresis, demonstrating successful amplification of the target genetic material.

Table 7. PCR Amplification Results

Parameter	Result
PCR Amplification	Positive
Target Gene Detection	Confirmed
Molecular Evaluation	Successful

PCR-based techniques provided rapid, sensitive, and reliable molecular evidence supporting the effectiveness of laboratory evaluation methods used in the present investigation.

CONCLUSIONS

The present study demonstrated the therapeutic potential of medicinal plant extracts, probiotic microorganisms, and green synthesized silver nanoparticles in relation to viral infection research. Phytochemical screening confirmed the presence of important bioactive compounds associated with antimicrobial, antioxidant, and immunomodulatory activities. Probiotic isolates exhibited desirable characteristics and inhibitory activity against pathogenic microorganisms, while silver nanoparticles displayed enhanced biological activity compared with crude plant extracts.

PCR-based molecular evaluation successfully confirmed the applicability of molecular approaches in advanced therapeutic investigations. The integration of medicinal plants, probiotics, nanotechnology, and molecular diagnostics provides a promising framework for the development of innovative strategies against rotavirus and other viral infections. Further in vivo studies and clinical investigations are recommended to validate these findings and explore their practical therapeutic applications.

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