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Research Article

Formulation And Evaluation of *Aegle Marmelos*' Nanoparticles and Their Incorporation into Bandages for Antimicrobial and Wound Healing Purposes

Shruti Chaudhary*, Rahela Anjum

Central India College of Pharmacy Lonara, Nagpur-441111, India.

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ABSTRACT

The present study involves the formulation of antimicrobial bandages using nanoparticles synthesized from *Aegle marmelos* leaf extract. *Aegle Marmelos* is a medicinal plant widely used in traditional ayurvedic medicine. It possesses significant antimicrobial, antidiabetic, and antioxidant properties. Nanoparticles were prepared through green synthesis and characterized using techniques such as UV-Vis spectroscopy, and particle size analysis, confirming their nanoscale range and presence of functional phytoconstituents. The biosynthesized AgNPs were evaluated for their antimicrobial activity using the agar well diffusion method. The nanoparticles exhibited significant zones of inhibition, demonstrating their effectiveness as antibacterial agents. Preliminary assessment of their potential in wound healing was based on their known phytochemical content and antimicrobial action, which contribute to infection control and promote a favorable healing environment. Polyvinyl alcohol (PVA) bandages incorporating nanoparticles are developed to enhance wound healing and antimicrobial properties. In this formulation, drug-loaded nanoparticles are synthesized and uniformly dispersed into a PVA solution. The mixture is then cast into thin films and dried to form flexible, biocompatible bandages. The PVA provides structural integrity and moisture retention, while the nanoparticles offer targeted therapeutic action such as antimicrobial or anti-inflammatory effects. This advanced formulation aims to improve healing efficiency and reduce infection risks in wound care applications.

INTRODUCTION

***Corresponding Author:** Shruti Chaudhary

Address: Central India College of Pharmacy Lonara, Nagpur-441111, India.

Email ✉: shruti.sc44@gmail.com

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***Aegle marmelos*:**

Aegle marmelos (Bael), a medicinal plant widely used in traditional medicine, contains a variety of phytochemicals including flavonoids, tannins, alkaloids, saponins, phenolic compounds, and terpenoids. These bioactive compounds are known for their broad-spectrum antimicrobial activity, antioxidant effects, and ability to stimulate tissue regeneration. Flavonoids and phenolics scavenge free radicals, reducing oxidative stress at the wound site, while tannins provide astringent properties that promote wound contraction and healing. Alkaloids contribute to antimicrobial effects by disrupting microbial cell walls.[1]

Nanoparticles for Enhanced Therapeutic Delivery

Despite the benefits of plant extract, the direct use of crude extracts faces challenges like poor solubility, limited bioavailability, and instability. Nanotechnology addresses these limitations as they are submicron-sized colloidal structures ranging from 1 to 1000 nanometers, engineered to improve the delivery and efficacy of therapeutic agents. In drug delivery systems, nanoparticles serve as carriers that protect active pharmaceutical ingredients (APIs) from degradation, enhance solubility, allow controlled and targeted release,

and improve bioavailability. Due to their small size and large surface area-to-volume ratio, they can cross biological barriers, interact at the cellular level, and facilitate site-specific drug action, minimizing systemic side effects. [2] [3].

Aim: Formulation and evaluation of *Aegle marmelos*' nanoparticles and their incorporation into bandages for antimicrobial and wound healing purposes.

Objectives:

1. To Identify and procure the drug
2. To extract active constituents
3. To synthesise nanoparticles
4. To characterize nanoparticles
5. To formulate bandages

Experimental work:

MATERIALS AND METHODS

Materials:

a. Plant Material

- leaves of *Aegle marmelos* collected from koradi region, Nagpur.

b. Chemicals –

- Ethanol, (manufactured by, Fujian C.C.S. Co., Ltd)
- Wagner's reagent (Iodine in potassium iodide)
- Lead acetate solution
- Ferric chloride solution

c. Laboratory Equipment –

- Soxhlet apparatus or maceration setup
- magnetic stirrer:(PSI 048)
- U.V and visible spectrometer:(Equiptronics)
- Particle size analyser: (Horiba).

Method:

1. Identification and procurement of drug

The leaves of *Aegle marmelos* (Bael) were collected and botanically authenticated by a qualified taxonomist. Collected leaves were shade-dried at room temperature (25–30°C) for 5–7 days and stored in airtight containers away from light and moisture until use.

2. Extraction of active constituents

Soxhlet Extraction:

50 g of the dried leaf powder was packed into a thimble and placed in the Soxhlet extractor. 250 mL of 95% ethanol was used as the solvent in the round-bottom flask. Extraction was carried out for 6–8 hours at the solvent's boiling point (~70°C) until the siphon tube solvent became colorless.

3. Synthesis of nanoparticles using *Aegle marmelos*

[Green synthesis of silver nanoparticles]

Silver nanoparticles can be synthesized using a plant extract as a reducing and stabilizing agent. In this method, a measured amount of plant extract,

10 ml is added to a silver nitrate (AgNO_3) solution of 90 ml. The silver nitrate solution is placed on a magnetic stirrer and stirred continuously at room temperature or slightly elevated temperature (around 40–60°C) for 30–60 minutes. , simultaneously the addition of plant extract drop wise was done.. During stirring, a color change (typically from pale yellow to brown) indicates the formation of silver nanoparticles. The nanoparticles can then be separated by centrifugation, washed, and dried for further use.

4. Characterization and Evaluation of *Aegle Marmelos* nanoparticles:

i. Colour Change:

A visual colour changes upon synthesis indicated the successful formation of nanoparticles.[7] [8].

ii. UV-Visible Spectroscopy:

UV-Vis spectroscopy was performed to confirm nanoparticle formation by identifying characteristic absorption peaks.[9] [10]

iii. Nanoparticle Size Analyzer:

Particle size distribution and average size were determined using a dynamic light scattering (DLS) nanoparticle size analyzer. [11]

● Process of Formulation of Nanoparticle Bandage Using PVA

Bandages: using PVA

Incorporating these nanoparticles into a polyvinyl alcohol (PVA) polymer matrix allows the development of flexible, biocompatible bandages. PVA, known for its excellent film-forming ability, mechanical strength, and non-toxicity, acts as an ideal vehicle for sustained delivery of *Aegle marmelos* nanoparticles, enhancing antimicrobial

action and accelerating wound healing through a synergistic effect.[12]

5. Preparation of Bandages Using PVA and Aegle marmelos Nanoparticles

i. Preparation of PVA Solution:

Accurately weigh 10% w/v of polyvinyl alcohol (PVA) powder and slowly add it to distilled water under constant stirring. Heat the mixture to about 80–90°C and stir continuously until a clear, homogenous PVA solution is obtained. Allow the solution to cool to room temperature.

ii. Incorporation of Aegle marmelos Nanoparticles:

Slowly add the nanoparticle suspension to the cooled PVA solution under continuous stirring to ensure uniform dispersion.

iii. Casting the Film:

Pour the PVA-nanoparticle mixture into a clean, leveled petri dish containing a base of cotton of thin film and spread the solution to desired thickness.

iv. Drying:

Allow the film to dry at room temperature or in a hot air oven at 40–45°C for 24–48 hours until a flexible, dry bandage film is formed.

v. Cutting and forming

Cut it into suitable sizes according to wound covering area and provide a support of medical tape to the cotton side of the film for better adhesion.

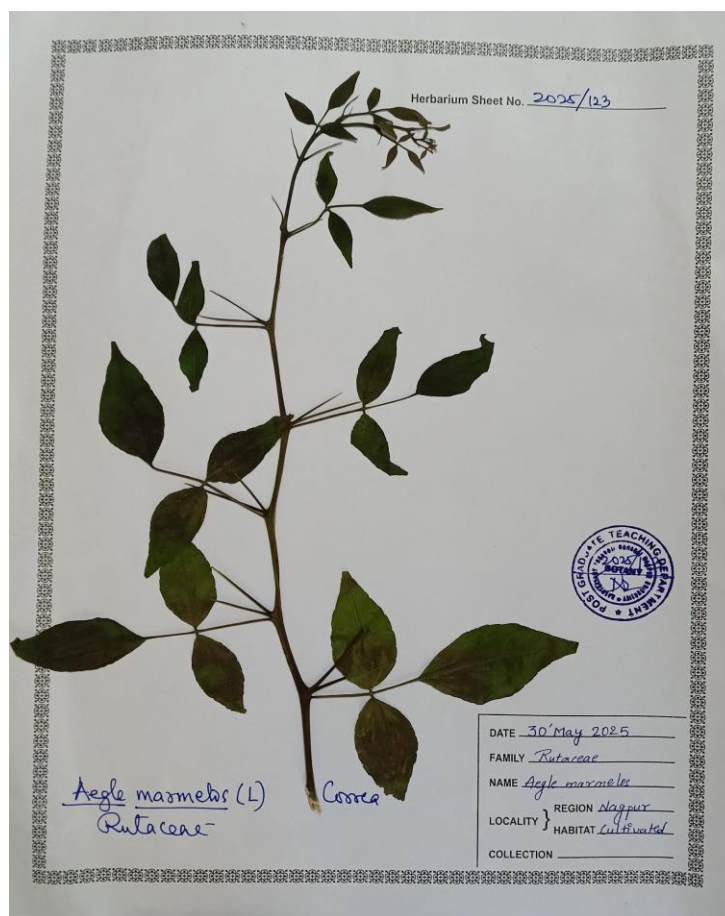
vi. Storage:

After placing the bandages under U.V light for 15 mins, store the prepared bandages in airtight containers or sterile packaging to maintain stability and to prevent contamination until further use.

RESULTS:

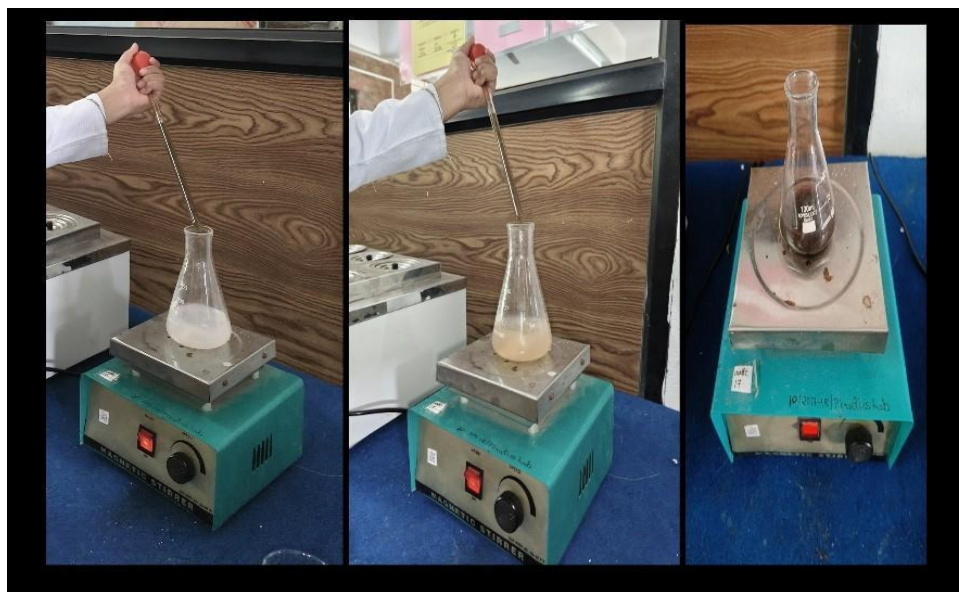
1. Authentication of plant

The collected *Aegle marmelos* leaves were authenticated to ensure correct botanical identity and suitability for further formulation studies.



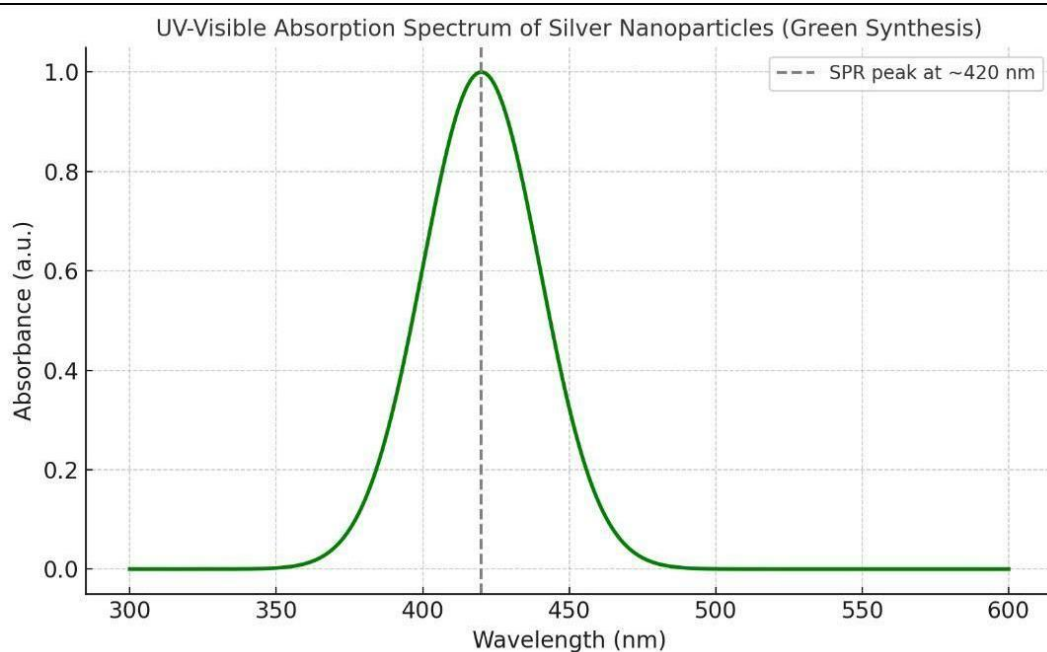
2. Characterization of Nanoparticles:

1. Colour change:



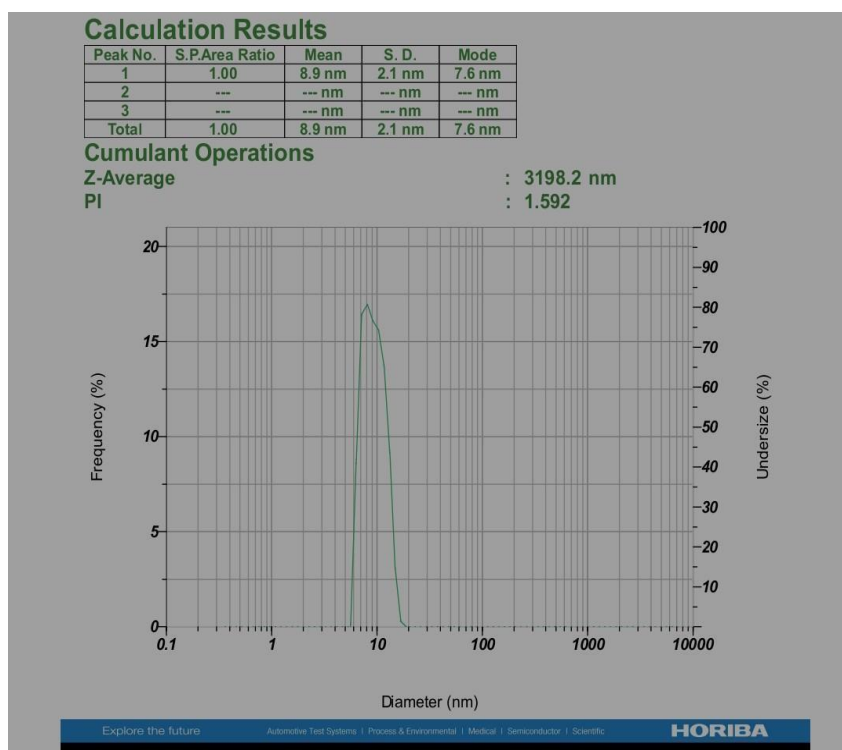
A visible colour changes from pale yellow to brown indicated the successful formation of nanoparticles.

2. U.V Spectroscopy



A characteristic absorption peak was observed at 420 nm, confirming nanoparticle synthesis.

3. Particle size analysis:



The nanoparticle size analyzer showed a particle size mode of 7.6 nm, indicating nanoscale particle formation.

3. Antimicrobial activity:



The synthesized nanoparticles exhibited notable antimicrobial activity, indicated by clear zones of inhibition on nutrient agar.

Sr. No.	Sample	Zone formation	Observation
1.	Nanoparticles loaded	Significant	Clear inhibition zone visible
2.	plain plant extract (control)	Less significant	No clear inhibition zone

4. Wound healing property:

The wound healing property of *Aegle marmelos* was confirmed in a study conducted by Jaswanth et al., where the plant extract demonstrated significant wound contraction and epithelialization in animal models (Jaswanth A., Akilandeswari, Loganathan V., Manimaran S., Ruckmani). Published in India journal. Accepted 5 December 2000, Revised 25 September 2001, *Indian J. Pharm. Sci.*, 2001, 63(1):41.



Drug-loaded nanoparticles were successfully incorporated onto a polymeric base and casted into bandages using medical tape as an adhesive support.

5. Casting of bandages

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