Uttar Pradesh Journal of Zoology

Volume 45, Issue 18, Page 161-169, 2024; Article no.UPJOZ.3970
ISSN: 0256-971X (P)

Biosynthesis of La_2O_3 Nanoparticles using *Lawsonia inermis* Leaf Extract

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i184434

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/3970

Original Research Article

Received: 27/06/2024
Accepted: 30/08/2024
Published: 03/09/2024

ABSTRACT

The article explains the biogenesis of lanthanum oxide nanoparticles (La_2O_3 NPs) utilizing *Lawsonia inermis* extract as an easy, safe, and efficient approach. The La_2O_3 NPs were synthesized by reducing $La(NO_3)_3.6H_2O$ with *Lawsonia inermis* leaf extract as a reducing agent. Fourier-transform infrared spectra were used to determine how the biomolecules in the *Lawsonia inermis* leaf extract contributed to the synthesis of La_2O_3 NPs. The UV–visible spectrum of the biosynthesized La_2O_3 NPs revealed absorption peaks at the La_2O_3 NPs' absorption maxima, which is 245 nm. As per the scanning electron microscopy investigation, the biosynthesized La_2O_3 nanoparticles (NPs) with a size of 30 to 60 nm had an uneven shape. EDAX confirmed that La and O were present in the La_2O_3 NPs. La_2O_3 NPs were tested for their antibacterial properties *Klebsiellapneumoniae* and Multi Drug Resistant *Staphylococcus Aureus*. The antibacterial activity of the biosynthesized La_2O_3 NPs is mild.

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Cite as: *Subramanian, P., and S. Alwin David. 2024. "Biosynthesis of La2O3 Nanoparticles Using Lawsonia Inermis Leaf Extract". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (18):161-69. https://doi.org/10.56557/upjoz/2024/v45i184434.*

Keywords: La_2O_3 NPs; biosynthesis; Lawsonia inermis; antibacterial activity.

1. INTRODUCTION

North Africa, Australia, and Southwest Asia are popular places to cultivate *Lawsonia inermis*, a tropical and subtropical plant in the Lythracea family. To treat amoebic dysentery, the leaves are used internally. They are also used to encourage menstrual flow and cure diarrhea. They are applied topically to soothe sore throats. Because of the astringent properties of the leaf extracts, the skin becomes hydrophobic. It is a helpful medication for external use against various skin and nail ailments because of this effect as well as a minor antibacterial and fungicidal action.

For this reason, the leaves are applied externally to cure wounds, ulcers, herpes, and a variety of skin conditions, including leprosy. To make mouthwash, an infusion of the leaves is combined with salt and tobacco. Lice are successfully killed with henna hair dye.

Although a number of approaches have shown that lanthanum nanoparticles can be produced chemically and physically, the need to find an alternative method arises from the need to use a large quantity of costly reagents, hazardous chemicals, extended times, and high temperatures. The green chemistry approach highlights that using natural plants has provided an easy-to-use, dependable, safe, and environmentally friendly method [1-19].

2. MATERIALS AND METHODS

2.1 Chemicals Used

Lanthanum nitrate hexahydride used for the synthesis of La_2O_3 NPs was purchased from nice chemicals. *Lawsonia inermis* leaves used in this work were collected from the local area (Thoothukudi, Tamil Nadu, India).

2.1.1 Preparation of *Lawsonia inermis* leaf extract

About 20g of fresh leaves of *Lawsonia inermis* were taken and washed thoroughly with distilled water to remove dust particles. These washed leaves were cut into very small pieces and boiled in 200 mL of distilled water for an hour in a round-bottom flask with a condenser. The leaf extract was filtered using Whatman No. 41 filter paper to obtain the pure leaf extract.

2.1.2 Biosynthesis of La_2O_3 nanoparticles

About 50mL of freshly prepared *Lawsonia inermis* leaf extract was added to 100 mL of 0.1M $La(NO_3)_3.6H_2O$ solution. This mixture was heated at 110°C for 1 hour. Then the synthesized La_2O_3 NPs were filtered, dried and calcined at 450°C for 2 hours.

2.1.3 Characterization

The JascoV-600 spectrophotometer was used to record the UV-visible spectra of the La_2O_3 NPs and the extract from *Lawsonia inermis* leaves. Thermo Scientific Nicolet iS5 FTIR spectrometer was used to measure FTIR. The average particle size of La_2O_3 NPs was determined by using XPERT-PRO X-ray diffractometer operating at a voltage of 40 kV and a current of 30 mA with Cu Kα radiation. A TESCAN MIRA3 XMU device was used to conduct energy dispersive X-ray analysis (EDAX) and scanning electron microscopy (SEM).

3. RESULTS AND DISCUSSION

Characterizations and applications of La_2O_3 NPs are described below by various techniques. The results obtained are discussed in detail as follows:

3.1 UV-Vis Diffuse Reflectance Spectroscopy

An absorption band of *Lawsonia inermis* at 256 nm is due to the presence of benzene and quinone with π-π^* electron transition. Another absorption band at 412 nm is due to the n-π^* transitions of carbonyl group in the quinone ring [1].

UV-Visible spectroscopy is one of the most powerful techniques for characterizing nanoparticles and it provides information about the optical properties of nanoparticles.

Fig. 2. shows the UV-visible spectrum of green synthesized La_2O_3NPs. The presence of sharp peaks at 245 nm can be attributed to valence band to conduction band transition in La_2O_3. It confirms the formation of La_2O_3NPs [2].

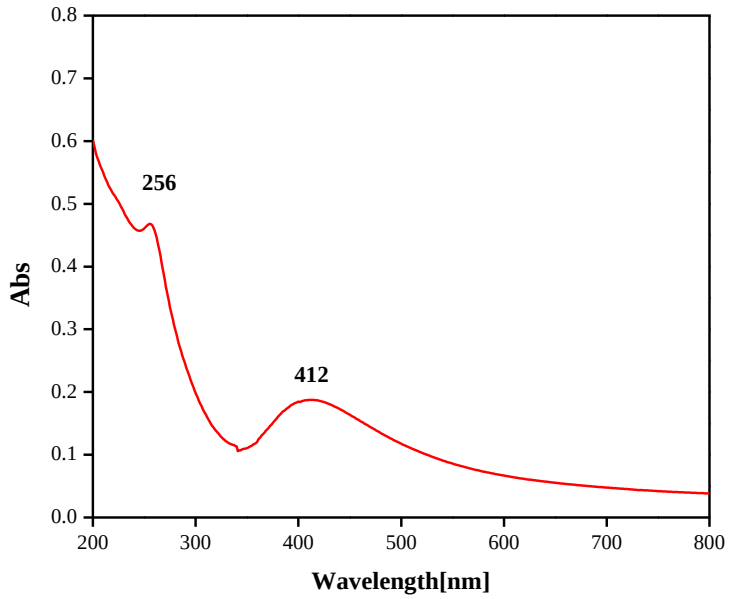

Fig. 1. UV-Vis spectrum of *Lawsonia inermis* leaf extract

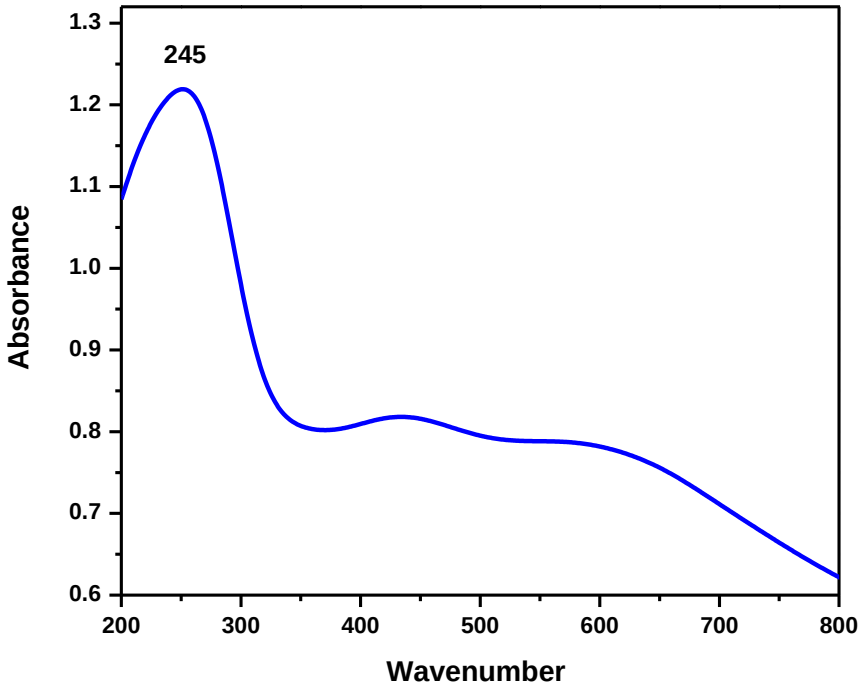

Fig. 2. UV-Visible diffuse reflectance spectrum of La_2O_3NPs

3.2 FTIR Analysis

A broadband centered at 3358 cm^{-1} in Fig. 3 is attributed to the stretching vibration of the hydroxyl group which can be found at the first lawsone aromatic ring. The broad absorbance is due to the intramolecular hydrogen bonding between the OH group and adjacent oxygen atom. The adsorption band which appeared at 1634 cm^{-1} is attributed to α, β-unsaturated carbonyl band. As seen in this IR spectrum, C=C is found as a weak band at 1384 cm^{-1} signifying aromatic C=C group [3]. The band at 1042 cm^{-1} is due to alkyl substituted ether [4] and C-N stretch in the sample. The peak observed at 567 cm^{-1} belongs to the stretching of La–O, and this peak has demonstrated the formation of La_2O_3 NPs [5].

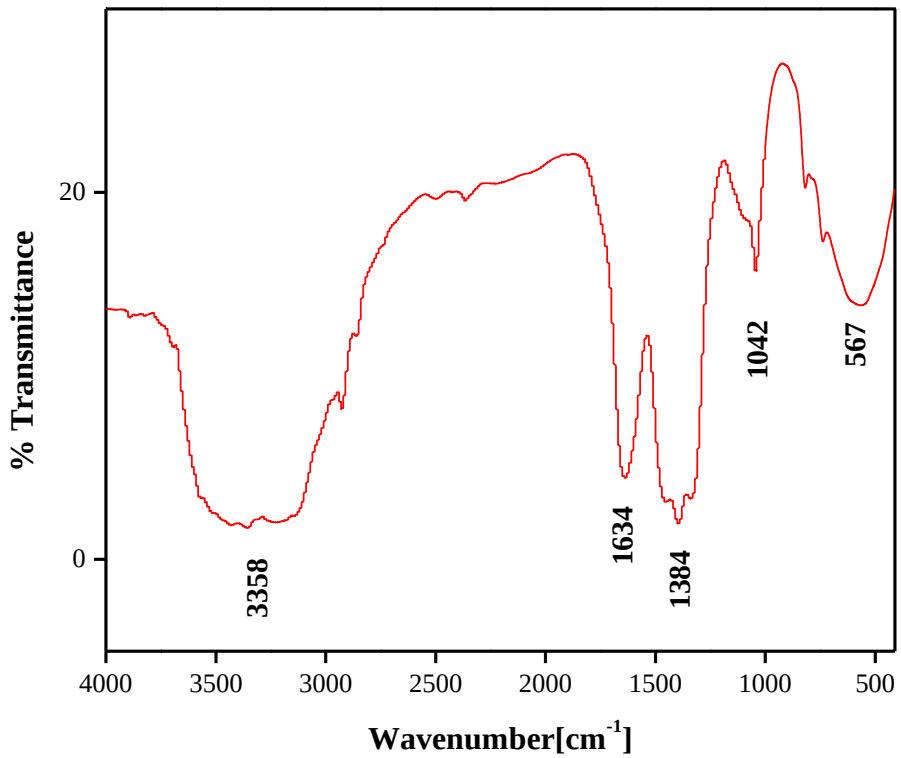

Fig. 3. FTIR spectrum of La_2O_3 NPs

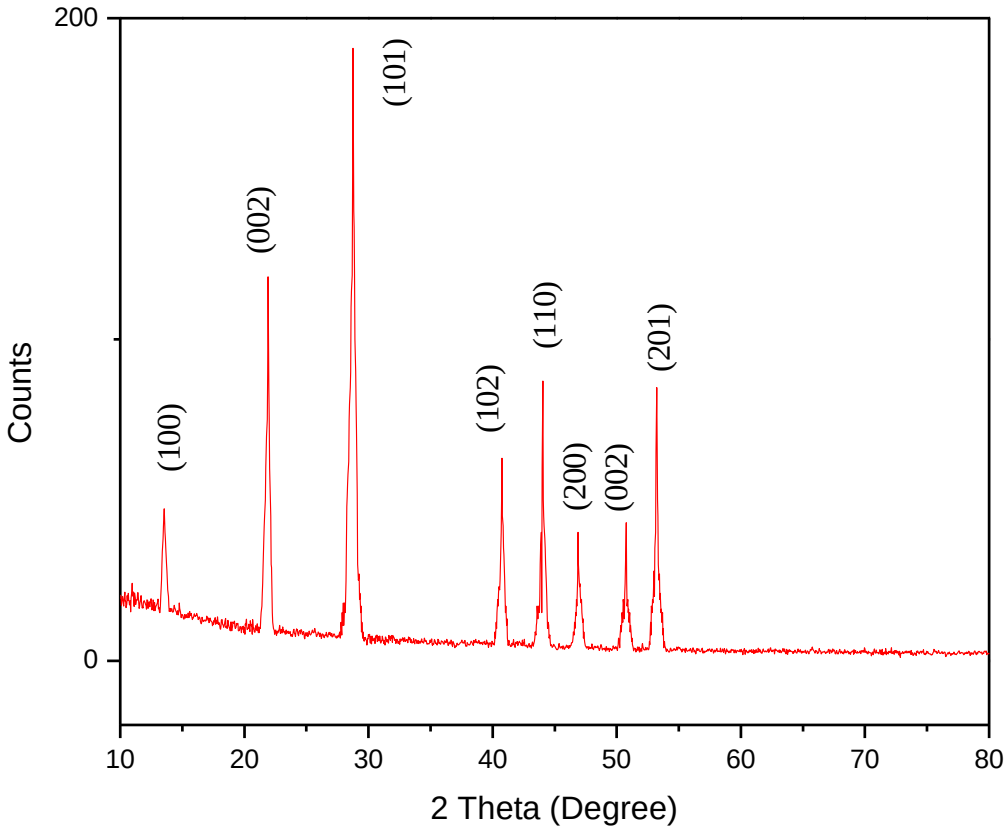

Fig. 4. XRD pattern of La_2O_3 NPs

3.3 X-ray Diffraction Analysis

The crystallite size can be evaluated using Debye-Scherer equation:

$$D = \frac{k \times \lambda}{\beta \cos\theta}$$

where D is the thickness (diameter) of the particle, λ is the wavelength of the X-ray beam, β is the full width at half maximum (FWHM) of the peak position in radians, k is the shape factor (0.9) and θ is the Bragg diffraction angle at peak position.

The analysis of XRD data using Debye-Scherer formula gives an average crystallite size of 24.99 nm. The crystallite size of the La_2O_3 NPs as estimated using the Scherrer formula is in the range of 14.67- 51.34nm.

The XRD peaks at 2θ values of 13.57°, 21.94°, 29.73°, 40.76°, 44.04°, 46.86°, 50.78° and 53.27° can be attributed to the (100), (002), (101), (102), (110), (200), (002) and (201) crystalline planes of La_2O_3 NPs, respectively which matched with JCPDS No. 05–0602. XRD pattern (Fig. 4) thus clearly illustrates the formation of La_2O_3 NPs [6].

3.4 Field Emission Scanning Electron Microscopy (FESEM)

The FESEM reveals the surface morphology and approximate size of the La_2O_3 NPs. The FESEM images (Figs. 5-7) show that La_2O_3 NPs exhibit irregular shape. The size of the La_2O_3 NPs obtained from FESEM is in the range of 30 – 6 nm.

3.5 Energy Dispersive X - ray Analysis (EDAX)

Energy Dispersive X-ray analysis (EDAX) was done to determining the atomic contributions of the constituents in the nanoparticles. In the EDAX of La_2O_3 NPs (Fig. 8), La and O have weight (%) 84.05 and 15.95 respectively. The atomic (%) is found to be 37.77 and 62.23 for La and O, respectively.

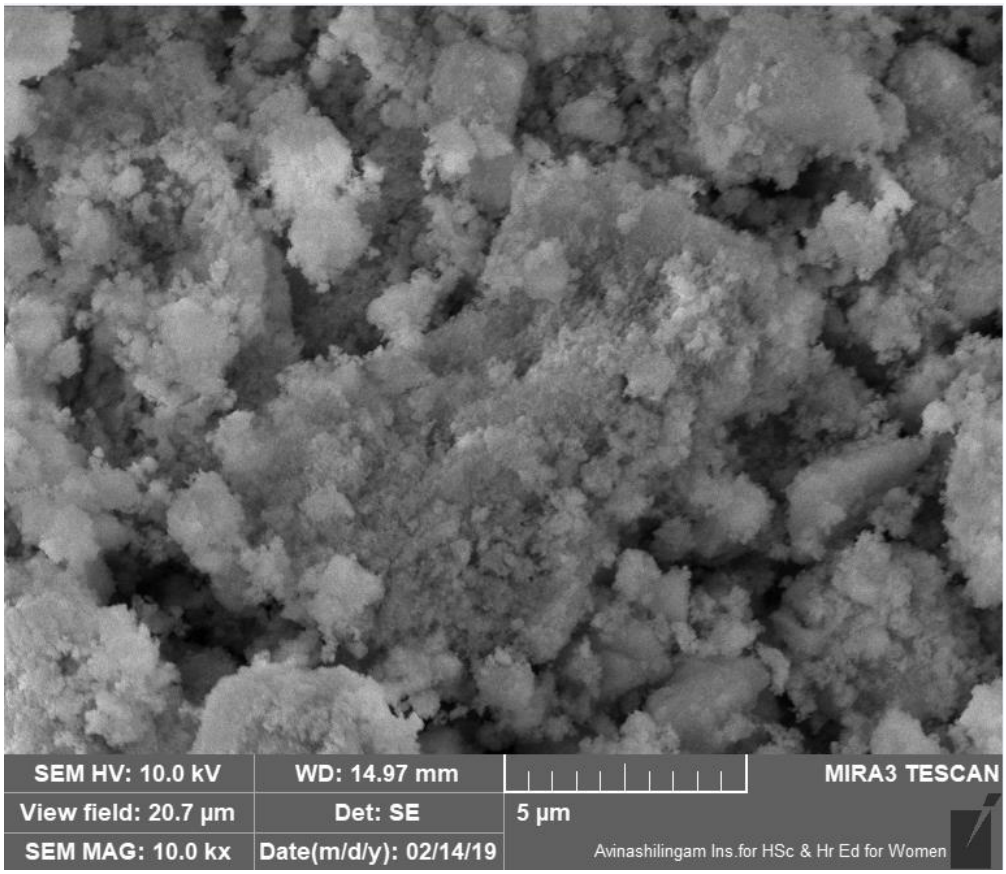

Fig. 5. FESEM image of La_2O_3 NPs in 5 µm scale

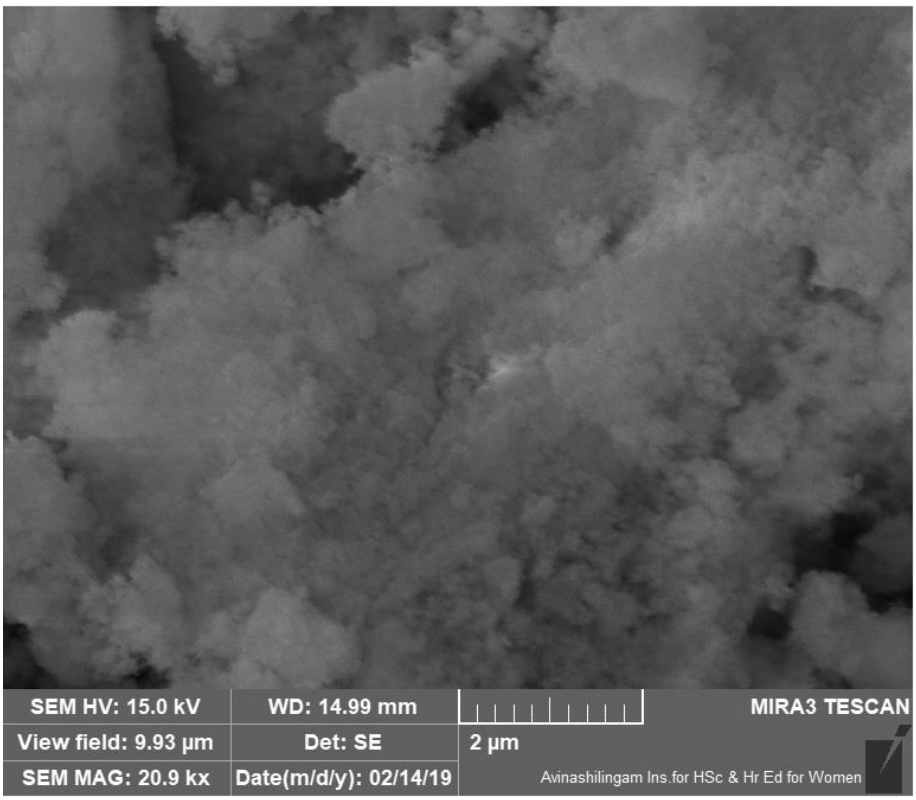

Fig. 6. FESEM image of La_2O_3 NPs in 2 µm scale

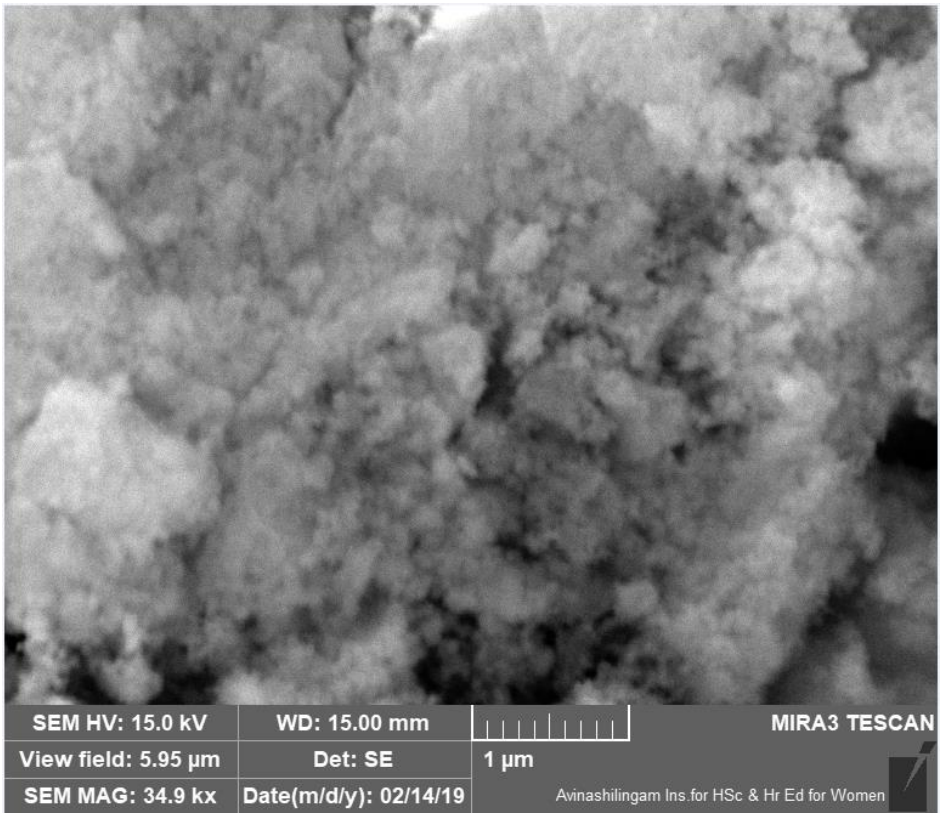

Fig. 7. FESEM image of La_2O_3 NPs in 1 µm scale

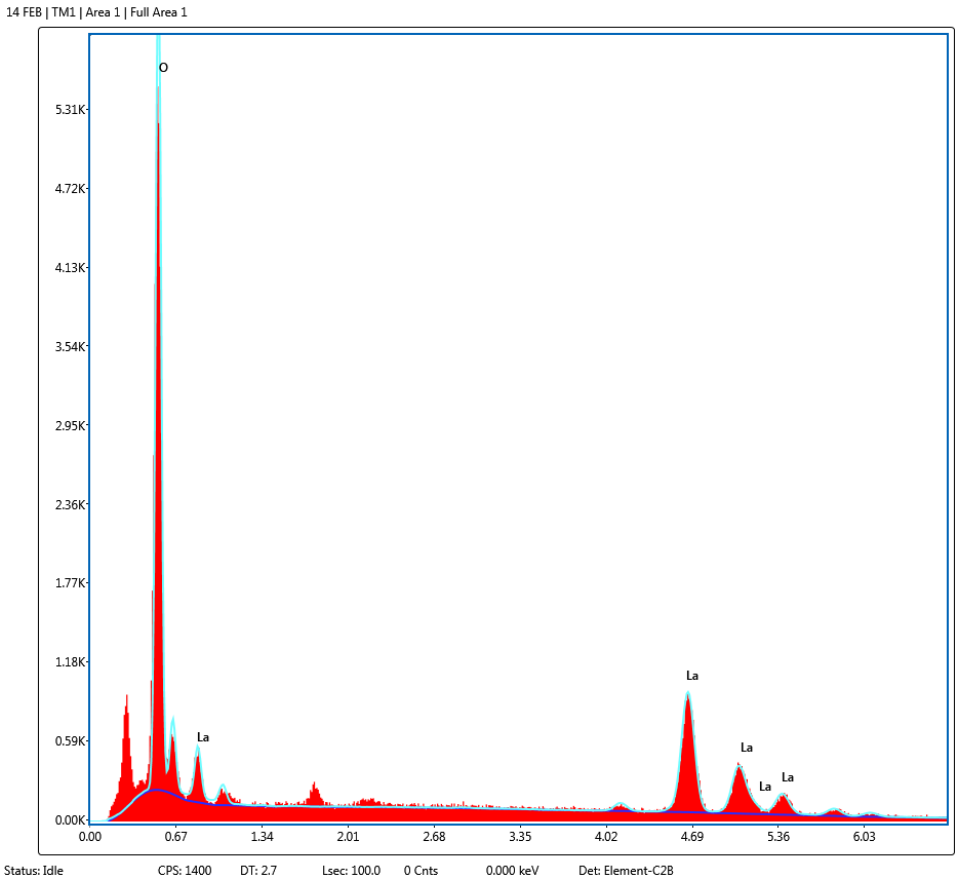

Fig. 8. EDAX spectrum of La_2O_3 NPs

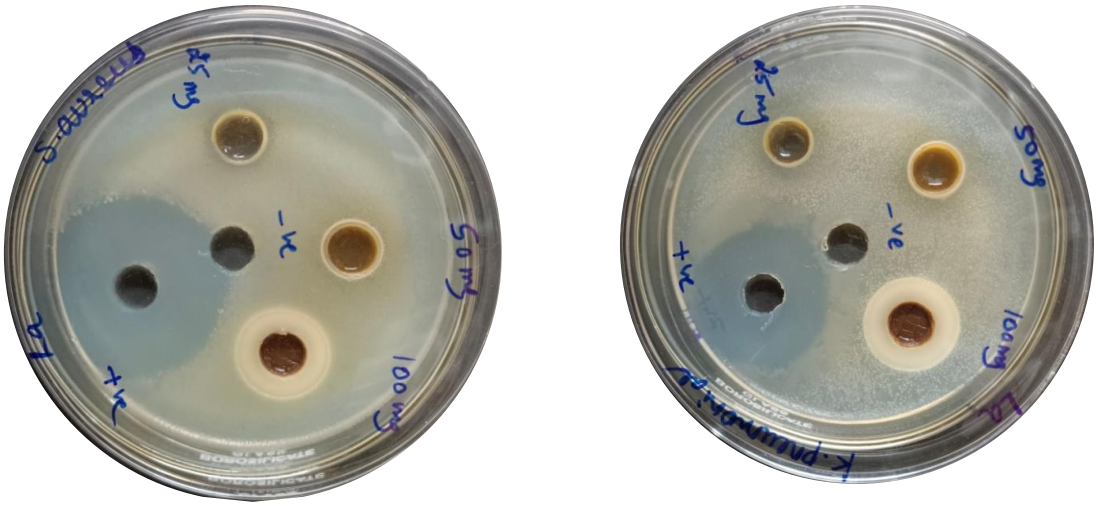

Fig. 9. Anti-bacterial activity of La_2O_3 NPs

Table 1. EDAX data of La_2O_3 NPs

Element	Weight %	Atomic %
La	84.05	37.77
O	15.95	62.23
Total	**100.00**	**100.00**

Table 2. Anti-bacterial Activity of Synthesized La_2O_3 NPs

Test Pathogens	Zone of Inhibition (ZOI) in mm				
	100 mg/mL	50 mg/mL	25 mg/mL	Positive Control	Negative Control
Multi Drug Resistant *Staphylococcus Aureus* (MRSA)	6	2	1	16	No ZOI
Klebsiellapneumoniae	7	2	1	13	No ZOI

Anti-bacterial activity was conducted against *Klebsiellapneumoniae* and Multi Drug Resistant *Staphylococcus aureus* (MRSA). The standard antibiotic chloramphenicol was selected as the comparison's control group (Positive Control). The antibacterial activity results demonstrated that all of the synthesized nanoparticles moderately inhibited both the bacterial strains of *Klebsiellapneumoniae* and Multi Drug Resistant *Staphylococcus Aureus*.

4. CONCLUSION

Bio synthesis of La_2O_3 NPs using the *Lawsonia inermis* leaf extract is demonstrated. The presence of sharp peaks at 245 nm in UV-Visible spectra confirm the formation of La_2O_3 NPs. Band at 567 cm^{-1} in FT-IR spectra confirm the presence of La–O bond. La_2O_3 NPs have average particle size of 24.99 nm, as evedent by XRD pattern. La_2O_3 NPs are found to be irregular in shape with variable size ranging from 30 to 60 nm, as evident by FESEM. EDAX confirms the presence of Lanthanum and Oxygen in the La_2O_3 NPs. The La_2O_3 NPs exhibit moderate antimicrobial activity against *Klebsiella pneumoniae* and Multi Drug Resistant *Staphylococcus Aureus*.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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