Tribulus Terrestris Linn Seed Extract for Biogenic Synthesis and Vanadium Oxide Nanoparticle Physicochemical Properties with Antimicrobial Evaluation

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ABSTRACT

Green nanotechnology offers a sustainable and environmentally responsible way to produce metal oxide nanoparticles by using less hazardous chemicals. Vanadium oxide nanoparticles (V_2O_3-NPs) were successfully produced in this study by using Tribulus terrestris Linn (Gokharu) seed extract as a stabilizing and reducing agent.UV-visible spectroscopy, which showed distinctive absorption in the ultraviolet area, further corroborated the creation of nanoparticles, which was first established by a noticeable colour shift Fourier Transform Infrared (FTIR) spectroscopy revealed the presence of hydroxyl, carbonyl, amide, and V-O functional groups, indicating the involvement of phytochemicals in the reduction and stability of the nanoparticles. X-ray diffraction (XRD) examination confirmed that the generated vanadium oxide nanoparticles were crystalline. Showed mostly irregular, rod-like, flake-like nanostructures with a small amount of aggregation. Energy Dispersive X-ray (EDX) examination verified the successful production of vanadium oxide nanoparticles by confirming the existence of oxygen and vanadium as the primary ingredients. When compared to the crude Tribulus terrestris seed extract, the produced nanoparticles demonstrated improved antimicrobial efficiency and demonstrated significant antimicrobial efficacy against strains of both Gram-positive and Gram-negative bacteria. The generated particles' enormous surface area and nanoscale size, which enable efficient contact with bacterial cell membranes, are responsible for the enhanced antibacterial activity. The established green synthesis process is a viable way to produce vanadium oxide nanoparticles with potential biological and antibacterial uses because it is straightforward, economical, quick, and environmentally safe.

Keywords: Vanadium oxide nanoparticles, Tribulus terrestris Linn, green synthesis, FTIR, XRD, SEM, TEM, EDX, UV-visible spectroscopy, and antibacterial activity.

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1.INTRODUCTION

The development of novel technologies and systems that are integrated from the nanoscale using biological materials and principles, and vice versa, is known as nanobiotechnology [1]. Nanoparticles are a cost-effective, straightforward, environmentally benign, and practical substitute for chemical processes due to their bio-based synthesis. Due to their remarkable properties in biomedical applications such as thermal treatment and cancer diagnosis, intracellular gene regulation, biolabeling, chemotherapy, cancer therapy, catalysis, and antioxidant and antibacterial activities, scientists have recently focused a lot of attention on the synthesis of NPs. [2-4]. In this research, we describe a green manufacturing method for vanadium oxide nanoparticles (V_2O_3NPs) utilizing Tribulus terrestris Linn seed extract. Terrestrial Tribulus Linn. Gokhru, a significant traditional medicinal plant in India, belongs to the Zygophyllaceae family. In the Ayurvedic, Siddha, and Unani medical systems, gokhru is significant due to its therapeutic value. Diuretic, demulcent, anti-inflammatory, anabolic, spasmolytic, muscle relaxant, hypotensive, and hypoglycemic qualities have been found in the plant's various parts.

This herb can help with pruritus-ani, calculus affections, crystalluria, urolithiasis, urine discharges, and sexual insufficiency. It can also be used as a supporting medication for asthma and cough. Phytochemical examination of the plant showed that it contained flavonoids, saponin, and carboline alkaloids.[5]. Nevertheless, its possible function in the biosynthetic process for creating vanadium oxide nanoparticles has not been investigated in any previous studies. Higher plants and animals contain the ultra-trace element vanadium [6]. Similar to its biological and pharmacological action, vanadium's essentiality, biodistribution, and toxicology are topics of growing interest and investigation. Vanadium metal is well-known for its many medicinal uses, which include antibacterial qualities, cardioprotective benefits, tumour suppression, and bone augmentation. Additionally, it plays a crucial role in the management of diabetes by mimicking insulin function and antidiabetic activity, growth factor and osteogenic actions, antitumoral properties, cardioprotective actions, and neurologic effects [7-9]. In this study, vanadium nanoparticles are made in an environmentally safe way using the aqueous extract of Tribulus terrestris Linn, a potential source of natural reducing and stabilizing agents. To thoroughly examine the biosynthesized vanadium oxide nanoparticles, we employed transmission electron microscopy (TEM), X-ray diffraction (XRD), and UV-visible spectroscopy. Zeta potential measurement showed that the stability of the nanoparticles was maintained for up to three months. For further uses, we also employed size-optimized vanadium oxide nanoparticles. To get a satisfactory yield of nanoparticles, a number of parameters were optimized, including the amount of plant extract, solvent, and reaction time. The produced vanadium oxide nanoparticles were physiochemically characterized using a variety of UV-VIS, FTIR, XRD, EDX, and SEM techniques. Using these methods, the effects of surfactant and calcination temperature on shape, size, and morphology were examined.

Fig.1 Tribulus Terrestris Linn Seed

2. Experimental

2.1 Collection of seed materials

The T. terrestris L. dried fruit bodies were gathered from a Mumbai, India, local market. After that, the seeds were thoroughly cleaned to get rid of any last bits of dust and surface contaminants using a fresh, dry towel. In order to totally eliminate the moisture, the fruit bodies were finally dried in the sun for a week.

2.2 Preparation of fruit extracts

Using a mortar and pestle, the dehydrated fruits were pulverized into a fine powder. 100 milliliters of deionized water were combined with five grams of powdered sample, and the mixture was brought to a boil for ten minutes. The fruit extract was filtered using Whatman No. 1 filter paper. once it had cooled. For later usage, the filtrate was kept at 4°C. [10]

2.3 Synthesis of vanadium nanoparticles

100ml were added to a 250 ml Erlenmeyer flask of T. terrestris L. aqueous filtrate extract. Fill the same vessel with 100 milliliters of a 5% sodium hydroxide (NaOH) solution. Next, weigh out eighteen grams of vanadium oxide (V_2O_3) and add it to the mixture. After adding all the ingredients, carefully heat the mixture to a warm temperature while stirring. In order to ensure complete mixing and interaction of the components, keep stirring under these circumstances for around half an hour. Following this first heating phase, turn off the heat and let the mixture stir for an additional four hours at room temperature. This guarantees that the reaction proceeds completely and uniformly. Store in the frights ensures that the reaction proceeds entirely and consistently. Keep in the refrigerator. This guarantees that the reaction proceeds completely and uniformly. Store for four days in the refrigerator. After three rounds of distilled water washing, the dark blue precipitate was centrifuged for 15 minutes at 12,000 rpm. Whatman filter paper was used to separate the solid residue, which was then completely dried and kept in a clean vial for additional chemical analysis and biological activity evaluation.

3.Characterization of nanoparticles

Spectroscopic, structural, and microscopic techniques were combined to assess the generation and functionality of the biosynthesized vanadium oxide nanoparticles. The optical characteristics and nanoparticle development were examined using UV-visible spectroscopy. A UV-Vis spectrophotometer with two beams (Model 2203) that operates with light wavelengths between 200 and 400 nm was used for this. Fourier Transform of Infrared (FTIR) The functional groups that support the stability and reduction of the nanoparticles were found using spectroscopy. The spectra were gathered between 4000 and 400 cm^{-1}.

A Rigaku Mini flex II diffractometer with Cu Kα radiation (λ = 1.54056 Å) was used for X-ray diffraction (XRD) studies over a 2θ range of 20° to 90° to examine structural characteristics such as phase composition and crystallinity. To confirm that the elements were distributed evenly and to determine the composition and purity of the nanoparticles, elemental mapping was used in addition to Energy Dispersive X-ray (EDX) spectroscopy, which was connected to a 20 kV JEOL JSM-6360 scanning electron microscope. A field emission scanning electron microscope (FE-SEM, Apreo 2S) running at 20 to 30 kV was used to examine the surface features, particle size, and shape. To learn more about the internal structure and form of the particles, transmission electron microscopy (TEM) was also employed. Additionally, the antibacterial efficacy of vanadium oxide nanoparticles the agar well diffusion method was used to measure resistance against Escherichia coli and Staphylococcus aureus. The effectiveness of the nanoparticles was evaluated using the size of the zones of inhibition.

4.RESULTS AND DISCUSSION

4.1UV-visible spectroscopic analysis

The produced vanadium oxide nanoparticles' UV–visible spectra revealed significant absorption in the UV range (200–380 nm), with an absorption edge at 370–400 nm. The successful production of vanadium oxide nanoparticles and their distinctive optical behaviour were confirmed by the absorbance's steady decline towards the visible region and stabilization above 600 nm.

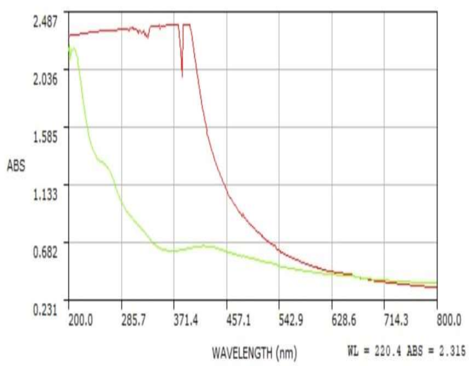

Figure 2: UV-visible spectra of nanoparticles of biosynthesized vanadium oxide

4.2 Analysis of X-Ray Diffraction (XRD)

The generated nanoparticles of vanadium oxide XRD showed diffraction peaks at roughly 18.7°, 20.2°, 26.4°, 30.7°, 31.6°, 34.2°, 36.8°, 45.6°, 48.3°, 50.8°, 63.2°, 72.5°, and 84.3° (73), (46), (52), (65), (61), (48), (35), and (25) counts, respectively. These diffraction peaks verify that the generated vanadium oxide nanoparticles are crystalline. Sharp diffraction peaks indicate good crystallinity, while the lack of any major impurity peaks demonstrates the high phase purity of the generated nanoparticles.

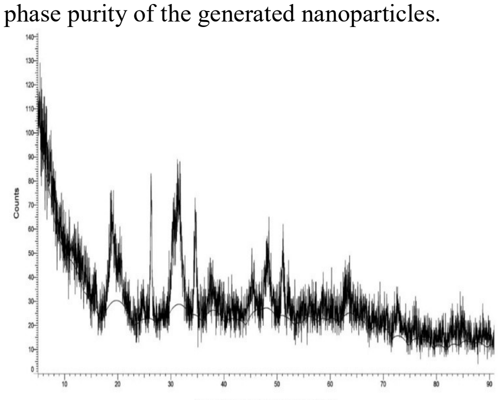

Figure 3: Vanadium oxide nanoparticle X-ray diffraction pattern

4.3 Fourier transform (FT-IR) spectroscopic analysis

The produced vanadium oxide nanoparticles' FTIR spectrum showed distinctive absorption bands at roughly 985, 934, and 808 cm⁻¹, which corresponded to the V=O stretching, V–O–V asymmetric stretching, and bridging V–O–V vibrations, respectively. The effective production of vanadium oxide nanoparticles is confirmed by these distinctive bands. O–H stretching of phytochemicals from the Tribulus terrestris Linn extract is responsible for the broad band seen at 3260–3910 cm⁻¹, suggesting their function as reducing and capping agents during nanoparticle production.

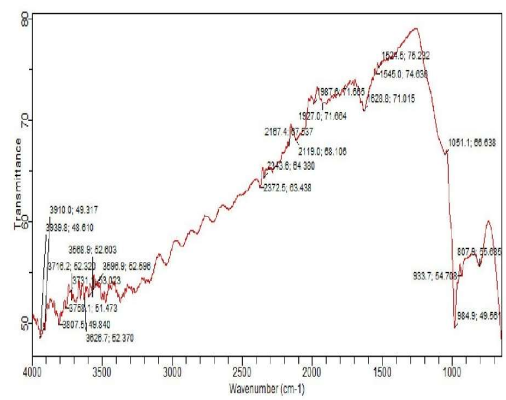

Figure 4: FT-IR spectra of nanoparticles of biosynthesized vanadium oxide

4.4 Analysis of Energy Dispersive X-ray Spectroscopy (EDX)

The usual O Kα (0.52 keV) and V Kα (4.95 keV) verified the production of vanadium oxide nanoparticles peaks in the EDX spectrum of the produced nanoparticles. The successful green manufacture of vanadium oxide nanoparticles utilizing Tribulus terrestris Linn extract was demonstrated by the quantitative analysis, which showed 30.8 weight percent oxygen and 25.9 weight percent vanadium.

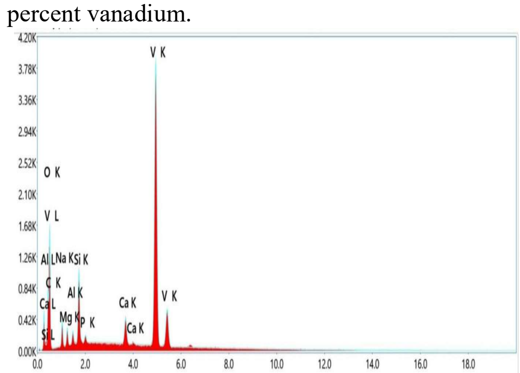

Figure 5: EDX spectrum of V_2O_3 nanoparticles

4.5 Analysis of Scanning Electron Microscopy (SEM)

The produced vanadium oxide nanoparticles have a rod-like, uneven flake-like morphology with notable aggregation in the SEM picture. A successful green synthesis is shown by the nanoparticles' uniform distribution and dense packing. The agglomerated aggregates are caused by the high surface energy of the nanoparticles and the capping impact of phytochemicals from the Tribulus terrestris Linn extract.

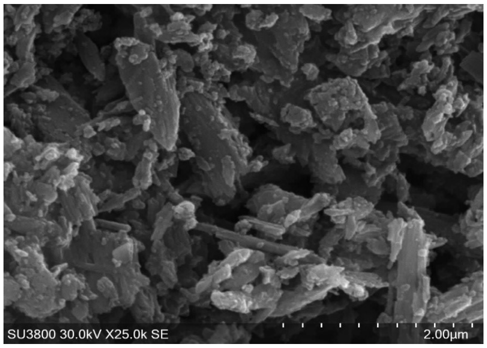

Figure 6: SEM picture of biosynthesised V_2O_3 NPs

4.6 Analysis of transmission electron microscopy (TEM)

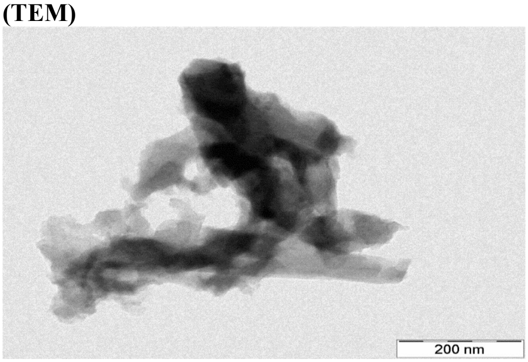

Figure 7: TEM picture of biosynthesised V_2O_3 NPs

The produced vanadium oxide nanoparticles had an uneven rod-like and flake-like shape with notable aggregation, according to the TEM picture. The nanoparticles come together to form nanometer-sized, linked nanoclusters. The successful green production of vanadium oxide nanoparticles utilizing Tribulus terrestris Linn seed extract is confirmed by the observed morphology.

4.7 Antimicrobial Properties

Both The effectiveness of vanadium oxide nanoparticles against bacteria was examined using both Gram-positive (Staphylococcus aureus) and Gram-negative (Escherichia coli) bacteria. The results revealed a significant increase in the places where bacteria could not grow, as seen in the image. We utilized ciprofloxacin as a positive control to assess the efficacy of other medications against bacteria. The places where no bacteria developed indicate that the nanoparticles killed the bacterium. These areas were 38 mm for E. coli and 43 mm for S. aureus.

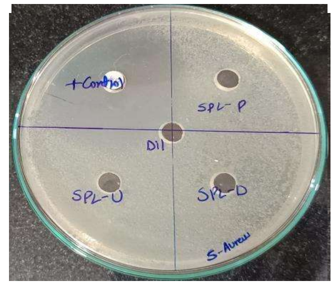

Figure 8: Images of biosynthesised V_2O_3 NPs antibacterial activity following a 24-hour incubation period

5.CONCLUSIONS

In conclusion, a straightforward, environmentally friendly method was used to successfully synthesis vanadium oxide nanoparticles (V_2O_3-NPs) utilizing the fruit extract of Gokharu (Tribulus terrestris). Vanadium oxide nanoparticle generation was confirmed by the UV–visible spectrum, and their crystalline character was shown by X-ray diffraction (XRD) examination. Phytochemicals with hydroxyl, carbonyl, and amide functional groups were identified by FTIR analysis as acting as stabilizing and reducing agents during the creation of nanoparticles. The produced nanoparticles primarily had rod-like and flake-like morphologies with mild aggregation, according to SEM and TEM investigations. By identifying oxygen and vanadium as the main components, EDX analysis confirmed the effective production of vanadium oxide nanoparticles. Additionally, Strong antibacterial activity was demonstrated by the generated nanoparticles against both Gram-positive and Gram-negative bacterial strains, indicating their potential as potent antimicrobial agents. The current green synthesis process is a potential strategy for the large-scale manufacturing of vanadium oxide nanoparticles for biomedical, pharmaceutical, and antimicrobial applications since it is affordable, quick, environmentally safe, and sustainable.

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