Educational Administration: Theory and Practice
2024, 30(1), 3149-3154
ISSN: 2148-2403
https://kuey.net/

Research Article

Green Synthesis, Characterization, And Antimicrobial Activities Of Manganese Dioxide And Cobalt Oxide Nanoparticles From Blumea Lacera Leaf Extract

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Citation: Sunil Ramrao Mirgane, et al (2024), Green Synthesis, Characterization, And Antimicrobial Activities Of Manganese Dioxide And Cobalt Oxide Nanoparticles From Blumea Lacera Leaf Extract *Educational Administration: Theory and Practice*, *30(1)* 3149-3154
Doi: 10.53555/kuey.v30i1.7058

ARTICLE INFO

ABSTRACT

The eco-friendly preparation of nanoparticles is a groundbreaking advancement in nanotechnology. The current study centers on a straightforward, efficient, and quick method for producing manganese dioxide and cobalt oxide nanoparticles and examining their anti-microbial properties. When leaf extract was added to potassium permanganate and cobalt chloride solutions, a color shift in the reaction mixture indicated the creation of nanoparticles. The manganese dioxide and cobalt oxide nanoparticles were analyzed using UV-vis spectroscopy, Scanning Electron Microscopy (SEM), and X-ray Diffraction techniques. The manganese dioxide and cobalt oxide nanoparticles prepared were spherical and had an average size of 5-10nm. Manganese dioxide and cobalt oxide nanoparticles were evaluated using an in vitro approach to demonstrate their anti-microbial activities. The current study explores new possibilities for enhancing medicinal applications by producing manganese dioxide and cobalt oxide nanoparticles using blumea lacera leaf extract for different health conditions. It also seeks to highlight the anti-microbial properties of medicinal plants to raise awareness among scientists and enhance the value of resources.

Keywords: Manganese dioxide nanoparticles, Cobalt oxide nanoparticles, Blumea lacera, green synthesis, anti-microbial activity

INTRODUCTION

There is an increasing interest in current scientific investigations to identify an alternate synthesis approach for metal and metal oxide nanoparticles due to the inescapable toxicity effects of the old method. Plant extracts from leaves, seeds, and flowers are crucial for chelating chemical compounds, offering an efficient, cleaner, and environmentally friendly method for producing nanoparticles. Green chemistry enables surface modification that significantly impacts the physical, chemical, electrical, and optical properties of nanoparticles. The use of green chemistry in creating biocompatible metal nanoparticles has become increasingly popular for possible uses in the field of biomedicine [1-2]. Incorporating green chemistry principles into nanotechnology is a crucial aspect of nanoscience research. The advancement of green nanoparticle production has increased the demand for environmentally friendly metal nanoparticle synthesis methods to prevent negative impacts in medicinal uses [3].

Nanotechnology encompasses a wide range of areas, from basic material research to personal care applications. The advancement of nanoparticles for delivering therapeutic substances has created new possibilities for enhancing medical treatment. Nanoparticles are highly intriguing in the scientific field as they serve to connect bulk materials with atomic or molecular structures. They display novel or enhanced qualities based on unique characteristics including size, distribution, and shape compared to bulk materials. Nanomaterials are found in sunscreens, toothpaste, sanitary ware coatings, and culinary products. There is an increasing demand for

ecologically benign methods of synthesizing nanoparticles of noble metals like gold, silver, and platinum, which are commonly used in items that come into contact with the human body [9]. Inorganic nanoparticles have been discovered to efficiently eliminate oxygen-derived free radicals [10].
The unique physicochemical features of MnO_2-NPs and CoO-NPs allow them to have a wide variety of applications in biochemistry and plant biotechnology [11]. Meanwhile, MnO_2-NPs and CoO-NPs significantly enhanced the growth factors of Blumea lacera leaf at concentrations below 10 mg L^{-1}. Our drive to prepare-mediated manganese dioxide and cobalt oxide nanoparticles and evaluate their anti-bacterial and antifungal properties was inspired by these discoveries. We present the eco-friendly production of manganese dioxide and cobalt oxide nanoparticles using Blumea lacera leaf. The nanoparticles were analyzed using UV-Vis, SEM, and FTIR techniques.

EXPERIMENTAL

Collection of Plant Materials and Preparation of Extract

leaf of Blumea Lacera were gathered from Local farmers in, the Jalna District of Maharashtra, India. The fresh leaves were used for all testing methods.

Chemicals

The investigation used potassium permanganate ($KMnO_4$), $CoCl_2.7H_2O$, and a solvent of the highest purity and analytical grade obtained from S. D. fine chem.

Extraction Preparation

The leaf of Blumea lacera components was cleaned and kept at a temperature of -4 °C. To produce the extract, about 5 g of ground, air-dried leaf of Blumea lacera samples were boiled with 100 ml of double-distilled water in an Erlenmeyer flask while being agitated constantly for 15 minutes. The extract was cooled to ambient temperature, filtered, and then stored at -4°C for future use.

Preparation of MnO_2-NPs

Manganese dioxide nanoparticles were prepared using an adjusted procedure based on earlier research studies [20-25]. Simply, mix a 0.01 M solution of $KMnO_4$ with the leaf of Blumea lacera extract in a 1:1 volume ratio. MnO_2 nanoparticles were promptly prepared using the reduction procedure. The mixture was agitated for 60 minutes and then left at room temperature for an additional 30 minutes to achieve a colloidal suspension. The mixture was centrifuged, washed with ethanol multiple times, and then dried at 40 °C under a vacuum to produce the MnO_2-NPs. The leaf of Blumea lacera has superior reduction capability against $KMnO_4$, as indicated by the exterior color change. Flowers meeting the criteria were chosen for additional processes. Following the confirmation test, the MnO_2-NPs were synthesized using the same process for additional characterization.

Preparation of CoO-NPs

Cobalt oxide nanoparticles were synthesized using a modified protocol derived from previous studies [20-25]. Specifically, a 0.01 M solution of CoCl2·7H2O was combined with an extract of Blumea lacera leaves in a 1:1 volume ratio. The CoO nanoparticles were rapidly formed via a reduction process. The mixture was stirred for 60 minutes and subsequently allowed to rest at room temperature for an additional 30 minutes to form a colloidal suspension. The resultant suspension was then centrifuged, repeatedly washed with ethanol, and dried at 40 °C under vacuum conditions to obtain the CoO-NPs. After verifying the synthesis, the same procedure was employed to produce additional CoO-NPs for further characterization.

Characterization techniques

UV-Vis Spectra analysis:

UV-vis spectrophotometer is used for absorption spectroscopy in the UV-visible spectral range. This refers to the utilization of light within the visible spectrum and the near UV and near-infrared areas. Absorption in the visible spectrum directly impacts the perceived color of the molecules. In this part of the electromagnetic spectrum, molecules experience electronic transitions. An ultraviolet-visible spectrophotometer (UV-vis) has been acquired from JASCO. A small portion of the sample was extracted for UV-vis spectrum analysis in the range of 200-800nm.

SEM Analysis:

Analyzed with a Scanning Electron Microscope (SEM) machine, namely the FEI Nova Nano SEM 450. The films in the sample were produced on a carbon-coated copper grid by depositing a minute quantity of the sample onto the grid.

Fourier Transform Infrared Spectroscopy:

The dried powder of the MnO_2-NPs and CoO-NPs were analyzed for the presence of functional groups that may have contributed to the synthesis of the MnO_2-NPs and CoO-NPs using Fourier transform infrared (Brucker) spectroscopy.

Anti-microbial activities

The disc diffusion assay evaluated the antimicrobial efficacy of MnO2-NPs and CoO-NPs synthesized via green methods. Sterile 6 mm discs (Hi-media) were impregnated with different concentrations of MnO_2-NPs and CoO-NPs: 10 µg/disc (10 µg/µl), 15 µg/disc (15 µg/µl), 20 µg/disc (20 µg/µl), 25 µg/disc (25 µg/µl), and 30 µg/disc (30 µg/µl). Culture plates were prepared by pouring 20 mL of Mueller-Hinton agar (MHA) medium into them. A bacterial suspension was swabbed uniformly onto the plates using a sterile cotton swab, and the plates were allowed to stand for a few minutes. The discs were carefully placed and pressed gently, then incubated upside down for 24 hours at 37°C. Ciprofloxacin discs (20 µg/disc) were the positive control on the MHA plates. Post-incubation, the susceptibility of the test organisms was determined by measuring the diameter of the inhibition zones using a Himedia zone scale. The data were then compiled for further analysis.

RESULTS AND DISCUSSION

A single-step process coats metal nanoparticles and causes a colour change from yellowish brown to brownish black. The colour shift confirmed the formation of MnO_2-NPs and CoO-NPs. The leaf of the Blumea lacera plant exhibits a superior ability to generate MnO_2 and CoO-NPs nanoparticles compared to other components of the plant including leaves, seeds, and fruits.

UV-Vis Spectroscopy studies

Figure 1 displays the UV-Vis absorption spectrum of manganese dioxide and cobalt oxide nanoparticles that were produced using a Cary 500 spectrophotometer within the wavelength range of 200 nm to 800 nm. Absorption in the near ultraviolet area is caused by electronic transitions within the sample. The MnO_2-NPs and CoO-NPs exhibited a peak at 314 nm and 339nm respectively, a characteristic feature of MnO_2 CoO nanoparticles. The nanostructure of MnO_2-NPs CoO shows that pure manganese dioxide and cobalt oxide nanoparticles have an absorbance peak at 398 nm and 365nm respectively. Nanostructured MnO_2 and CoO nanoparticles display a prominent absorption band at 314 nm and 339nm respectively, caused by charge-transfer processes from oxygen 2*p* to manganese 3*f*, which disrupts the typical *d-d* spin-orbit splitting of the Mn and Co 3*d* state. The wide absorption shoulder in the UV region is caused by the self-assembly of nanoparticles, as proven by UV-vis analysis.

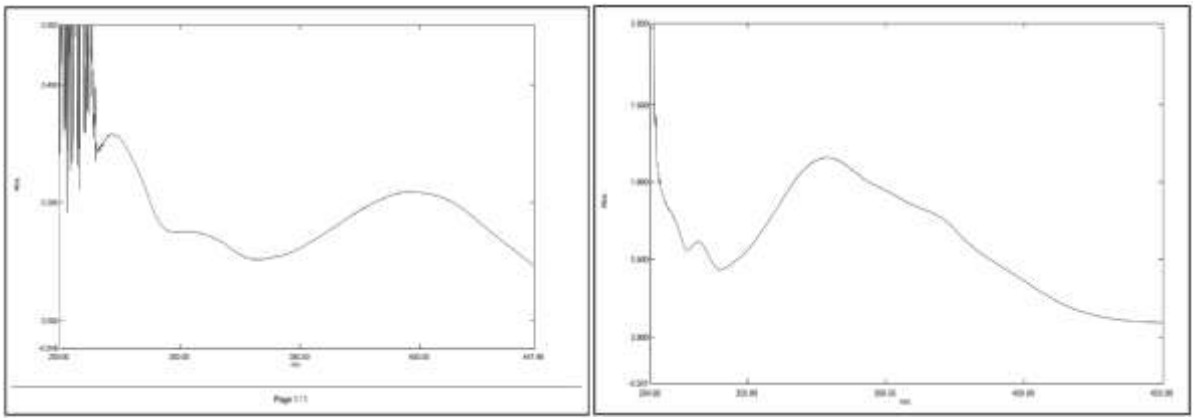

Figure 1. UV-vis spectra of MnO_2-NPs and CoO-NPs

SEM Analysis

The scanning electron microscope (SEM) image (**Figure 2**) displays MnO_2-NPs and CoO-NPs with an average size of 5.09 and 5.10nm at an accelerating voltage of 25 kV, with a working distance of 25mm. The particles appear predominantly spherical or flower-like, with some exhibiting elongated shapes, and are observed to be agglomerated.

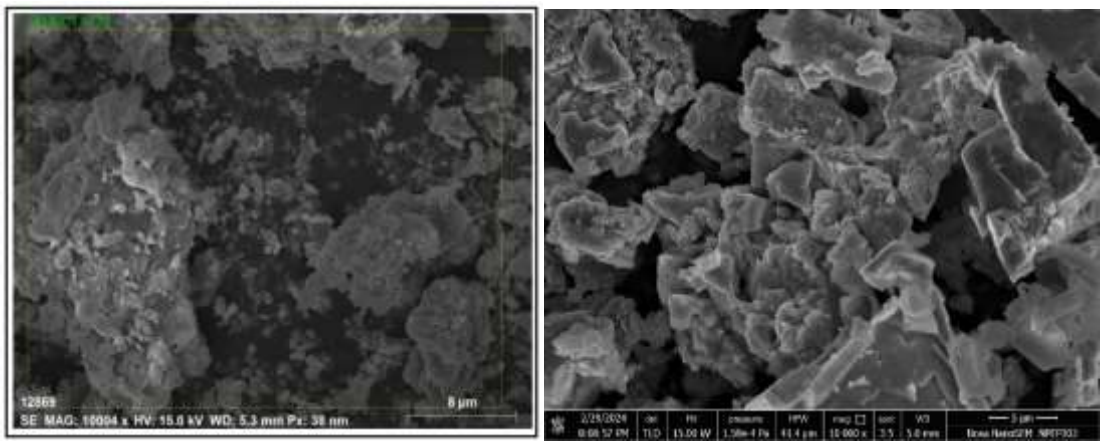

Figure 2: SEM spectra for MnO_2-NPs and CoO-NPs

Fourier Transform Infrared Spectroscopy:

Figure 3 displays the FTIR spectra of pure Blumea lacera leaf extract and MnO_2-NPs and CoO-NPs. The Blumea lacera leaf extract spectrum displays many frequencies between 2100 and 1000 cm^{-1}, including C=O stretching at 1680 cm^{-1} from the organic acid and secondary amine at 1585 cm^{-1} from the proteins in the extract. The absence of the peak at 1680 cm^{-1} in the MnO_2-NPs CoO-NPs spectra compared to the spectra indicates that the acid groups in the Blumea lacera leaf extract are responsible for the reduction process. The bands changing from 1631 cm^{-1}, 1450 cm^{-1}, and 1052 cm^{-1} suggest that proteins are directly involved in maintaining the sol particles.[14] The FTIR spectra displayed a wide absorption band at 3461 cm^{-1} primarily attributed to OH groups present on the surface of the nanoparticles. The spectra displayed a prominent peak at 511 cm^{-1} which is the distinctive peak of MnO_2-NPs CoO-NPs. A new signal at 1052 cm^{-1} was detected, confirming the production of nanoparticles.

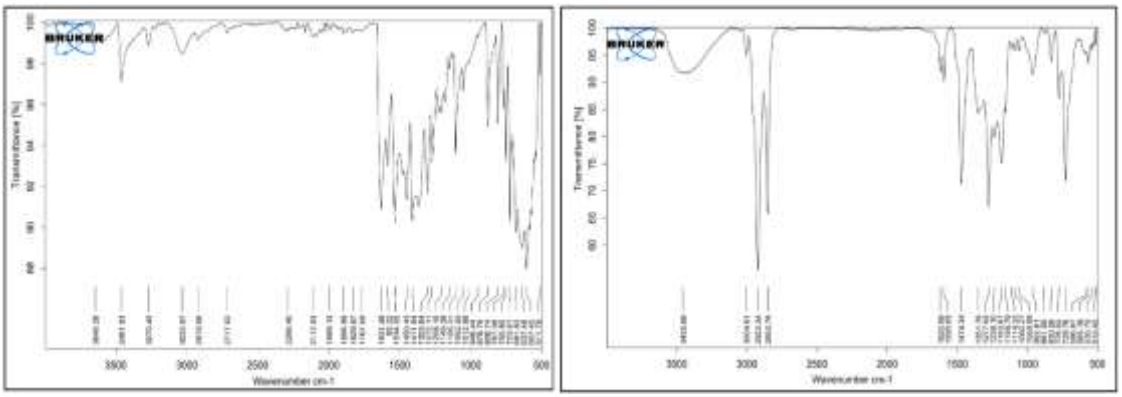

Figure 3: FTIR spectrum for MnO_2-NPs and CoO-NPs

EDAX Analysis:

Figure 4 displays the Energy Dispersive Spectroscopy (EDAX) results of MnO_2-NPs synthesized by wet methods, confirming the presence of manganese (Mn) and oxygen (O) in terms of weight percentage. The EDAX analysis indicates peaks corresponding to manganese and oxygen in the as-prepared sample, with minimal impurities such as potassium, chlorine, nitrogen, and sulfur. **Table 1** MnO_2-NPs exhibit a characteristic optical absorption peak at around 5 KeV as a result of surface Plasmon resonance.

Figure 4 presents the Energy Dispersive X-ray Spectroscopy (EDAX) analysis of CoO nanoparticles synthesized via wet methods, which confirms the presence of cobalt (Co) and oxygen (O) based on their weight percentages. The EDAX spectra reveal distinct peaks corresponding to cobalt and oxygen in the synthesized sample, with negligible impurities such as potassium, chlorine, nitrogen, and sulfur. As shown in **Table 1**, the CoO nanoparticles exhibit a characteristic optical absorption peak at approximately 5 KeV, attributed to surface plasmon resonance.

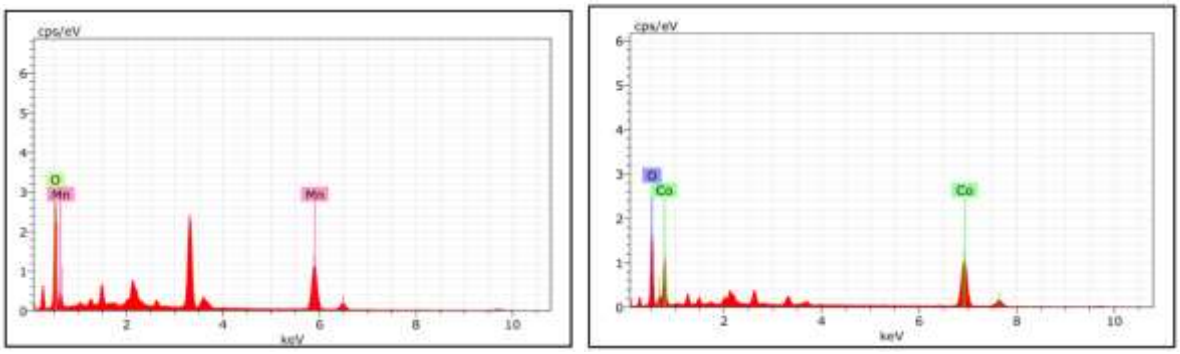

Figure 4: EDAX spectrum for MnO_2-NPs and CoO-NPs

Table 1: Percentage data of MnO_2-NPs and CoO-NPs

Spectrum: OBJECT1 723

El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Mn	26	K-series	38.36	72.11	42.56	1.18
O	8	K-series	14.83	27.89	57.44	1.94
Total:			53.19	100.00	100.00	

Spectrum: OBJECT1 735

El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Co	27	K-series	57.62	82.86	56.75	1.78
O	8	K-series	11.92	17.14	43.25	1.60
Total:			69.54	100.00	100.00	

Anti-bacterial activities

The inhibitory effects of 25 µg, 50 µg, and 75 µg doses of MnO_2 and CoO nanoparticles on bacterial growth on agar plates. An increase in antibacterial activity was observed with higher concentrations of MnO_2 and CoO nanoparticles. The respiration mechanism at the bacterial cell membrane causes nanoparticles to dehydrogenate upon adsorption onto the bacterial cell. The bacteria deactivate their enzymes before reacting with the nanoparticles, resulting in the production of hydrogen peroxide, which is lethal to the bacteria.

CONCLUSION

The eco-friendly green synthesis from Blumea lacera leaf extract resulted in the preparation of nanoparticles that are rather homogeneous in size and shape. The nanoparticles exhibited effective anti-bacterial activities. This quick synthesis approach shows potential for preparing nanoparticles. In the future, a large quantity of MnO_2-NPs and CoO-NPs should be prepared using different plant extracts. Their therapeutic properties should be analyzed to create affordable natural solutions for treating diverse disorders. This approach will be beneficial in environmental, biotechnological, pharmaceutical, and medicinal applications.

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