Photocatalytic and Biological Applications of Chromium Oxide Nanoparticles Fabricated from Terminalia Chebula Fruit Extract

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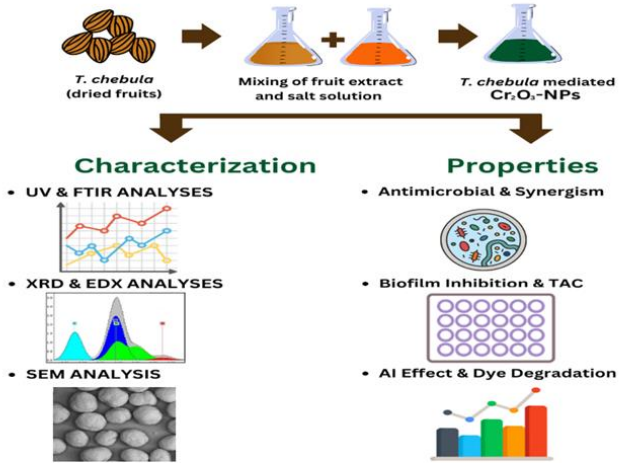
ABSTRACT

In the present investigation, the fruit extract of *T. chebula* was employed to successfully synthesize Cr_2O_3-NPs. FTIR, XRD, EDX, SEM, and UV-Vis spectroscopy were performed for successful characterization of the green synthesized Cr_2O_3-NPs. Compared with commonly used antibiotics, green-synthesized Cr_2O_3-NPs demonstrated impressive bacterial suppression against clinical pathogens. Even at lower dosages, the green synthesized Cr_2O_3-NPs showed potent anti-biofilm, antioxidant, anti-inflammatory, and photocatalytic dye degradation properties. Hence, the synthesis of biocompatible and biologically active NPs utilizing *T. chebula* fruit extract is a reliable, convenient, affordable, and environmentally friendly process that can be pursued for multidimensional applications.

Keywords: Antimicrobial, Chromium Oxide, Nanoparticles, Photocatalytic Degradartion, *T. chebula*.

INTRODUCTION

The plant-based synthesis of metallic nanoparticles (NPs) has garnered substantial consideration during the previous few years pertinent to their unique features and wide applicability. Plant-mediated synthesis of NPs is an easy, quick, and direct technique, and NPs synthesized using this approach are more compatible and less dangerous (Gebre, 2022). Aqueous plant extracts contain a variety of phytochemicals (flavonoids, terpenoids, alkaloids, and polyphenols) that act as reducing and capping agents during NP synthesis (Shamprasad *et al*., 2019). *T. chebula* fruits contain high levels of tannins, flavonoids, ascorbic acid, phenolic acids, terpenoids, alkaloids, and glycosides. These bioactive substances help avoid long-term illnesses and play an important role in eradicating widespread human infections (Nigam *et al*., 2020) (Khan *et al*., 2022). Recently, significant antibacterial potential of TiO_2-NPs, CuO-NPs, and MgO-NPs synthesized from aqueous fruit extracts of *T. chebula* has been reported (Devilakshmi & Ramasamy, 2023) (Lalithamba *et al*., 2023) (Munusamy and Rajeshkumar, 2023).



OBJECTIVE

The purpose of this study was to synthesize and characterize chromium oxide nanoparticles (Cr_2O_3-NPs) from *T. chebula* fruit extract. Furthermore, this study aimed at exploration of antibacterial, anti-biofilm, anti-inflammatory, antioxidant, and photocatalytic dye degradation activities of the fabricated NPs.

METHODOLOGY

The *T. chebula* fresh fruit extract was used for phytochemical screening by performing different tests according to standard protocols. Cr_2O_3-NPs were synthesized from fruit extract of *Terminalia chebula* as stabilizing as well as reducing agent. The extract was added dropwise to the $K_2Cr_2O_7$ solution until the color changed, and was further subjected to continuous stirring at 60 °C for approximately 40 min. The characteristics of NPs were assessed using several analytical techniques. UV-visible spectrophotometry was used to observe the spectral absorption patterns. FTIR spectroscopy was performed to assess the chemical constitution. XRD was used for the determination of crystal structure of the NPs. Powdered samples were placed in an X-ray diffractometer with a Cu-Kα beam (wavelength = 0.154 nm) and a nickel filter between 50 and 500 µm. The elemental constituents of the NPs were elucidated by EDX spectrometry. SEM analysis was used to decipher the morphological appearance of the NPs at a magnification upto 2000X. The antimicrobial activity was evaluated against 12 clinical isolates (*S. aureus, K. pneumoniae, S. enterica, Acinetobacter* spp., *E. coli, Enterobacter* spp., *P. vulgaris*, *P. aeruginosa,* and *C. albicans*) using the well diffusion method. MIC was also calculated. Antibiotic susceptibility testing employed the Kirby-Bauer disc diffusion method. NPs' synergistic antimicrobial activity was then determined using selected antibiotic discs. Antibiotics soaked in the NP suspension were placed at equal distances on the MHA plates and incubated at 37 °C overnight. FICI values established the presence or absence of synergism between the NPs and antibiotics used. Mueller-Hinton broth was used in biofilm inhibition assay and absorbance was measured at 620 nm. Total antioxidant capacity was determined using the phosphomolybdenum assay. The anti-inflammatory potential of the NPs was assessed using a functioning solution of BSA. The photocatalytic dye degradation potential of the NPs was evaluated against two common dyes, methyl red, and methylene blue by measuring absorbance was at 525 nm and 625 nm.

RESULT

A sharp peak at 450 nm in the UV-visible analysis validated the fabrication of nanoparticles. FTIR signal at 652.81 cm^{-1} authenticated the Cr-O bond formation. XRD validated the crystal structure of the Cr_2O_3-NPs with a crystal size of 22 nm. EDX spectrum demonstrates that Cr and O are the principal elements. SEM divulged the morphology with size ranging from 50 to 80 nm for the irregular rocky clusters of the synthesized nanoparticles. Cr_2O_3-NPs demonstrated excellent antimicrobial effects against all isolates, which were superior to those of commercially available antibiotics. The average MIC was calculated to be 2.9 µg/ml. However, Cr_2O_3-NPs showed synergy with none of the tested antibiotics (FICI >1). Furthermore, Cr_2O_3-NPs showed considerable dose-dependent biofilm inhibition (65–85% at the highest concentration), antioxidant activiity (30–45%), and anti-inflammatory potential (40–44%). Finally, the Cr_2O_3-NPs enhanced the photocatalytic degradation of methylene blue from 20% to 35% and methyl red from 40% to 52%.

CONCLUSION

Taken together, these findings suggest that *T. chebula*-mediated Cr_2O_3-NPs are promising candidates for future applications in biomedicine and environment.

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