ORIGINAL ARTICLE

Green Synthesis of Iron Nanoparticles by Aqueous Extract of Zingiber Officinale: Characterization and Inhibitory Effect on Escherichia Coli Investigated

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Abstract

Purpose: The goal of biomedical researchers is to overcome harmful bacteria' resistance to antibiotics by developing new active chemicals quickly, cheaply, easily, and environmentally.

Materials and Methods: The goal of biomedical researchers is to overcome harmful bacteria' resistance to antibiotics by developing new active chemicals quickly, cheaply, easily, and environmentally.

Results: This suggests that the nanocomposite was created and the reaction occurred. FT-IR, TEM, and UV-Vis spectroscopy were utilized to analyze phytosynthesized Fe-NPs. Overall, the phytosynthesized Fe-NPs show activities that enable their use in various biomedical and biotechnological applications. Additionally, the antimicrobial effect was investigated against Gram-negative bacteria (Escherichia coli).

Conclusion: The antibacterial activity of E. coli was determined, and the highest zone of inhibition was observed at the concentration of 100 µg/mL.

Keywords: Nanoparticles; Green Synthesis; Iron Oxide Nanoparticles; Antimicrobial Activity.

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1. Introduction

Nanoparticles (NPs) are gaining importance in scientific research due to their unusual size and properties. NPs play a crucial role in many applications and significantly alter a wide range of technical domains. Researchers have become particularly interested in nano-biotechnology [1-8]. Numerous metal oxide NPs are developed for pharmaceutical, drug delivery, cosmetic, tissue engineering, and biomedical applications as a result of the advancements in nano-biotechnology. Many researchers are currently striving to create a biocompatible medication that is effective in treating both cancer and a variety of infectious disorders [9 - 16].

The primary use of nanomaterials in many scientific and technological domains is expected to be led by nanotechnology. The field of nanotechnology involves the synthesis of NPs with practical applications in biology, including medication delivery [17-24]. Due to its extensive application in both biological and geological processes, iron is one of the most relevant infrastructures. Because of their vital function in everyday use and lower toxicity, iron oxide NPs are one of the most widely employed particles [25-31]. Hematite and magnetite, the two forms of iron oxides found in nature, are the only ones that are used in scientific research. Iron oxide NPs, which ranged in width and size from 10 to 100 nm, were essential to the development of nanotechnology [32-37].

Superparamagnetic is one of the amazing new phenomena that magnetite NPs exhibit. The magnetic behavior of individual NPs is primarily influenced by surface effects and finite sizes [38- 40]. Because of their high chemical stability and non-toxicity, magnetite NPs have garnered significant interest for a variety of significant technological and biomedical applications, including drug delivery, magnetic separation, cancer hyperthermia, and the improvement of Magnetic Resonance Imaging (MRI). Various methods have been reported to date for preparing magnetite NPs; these include co-precipitation (Massart's method; co-precipitation of Fe+2 and Fe+3 salts in saturated base solutions), microemulsions, solvothermal processing, and high-temperature organic phase decomposition [41- 45]. However, the majority of these methods involve chemical synthesis.

Ginger is a chemically rich source of flavonoids and polyphenolic compounds, including borneol, geraniol, limonene, linalool, alphazingiberene, gingerols, shagols, zingerone, paradol, terphineol, and terpenes. According to recent research, ginger can be utilized to create NPs. According to a report by Kebede Urge, S. *et al.* [46; 47], an aqueous extract of ginger was utilized to create gold and silver NPs. Therefore, the goal of this study is to assess Zingiber officinale's effectiveness in producing iron NPs through biogenic synthesis.

2. Materials and Methods

2.1. Materials

Chemicals, including ferrous chloride tetrahydrate ($FeCl_2.4H_2O$), were acquired from Sigma Aldrich for the study. Every experiment used distilled water.

2.2. Preparation of the Root Extract

We gathered fresh ginger from the nearby market. To get rid of the impurities in the skin, ginger was thoroughly cleaned and submerged in water. After that, the roots were fully dried by air to eliminate any remaining moisture. After peeling the outer skin off of some dried ginger, 5g of the ginger was weighed. After cutting it into pieces, it spent about an hour at 50°C in a hot air oven. Using a mortar and pestle, the dried roots were crushed while slowly adding 25 milliliters of deionized water. Whatman No. 1 Filter paper [48] was used to filter the extract. To be used later, the extract was kept at 4°C (Figure 1).

Figure 1. Plant extracts solution

2.3. Preparation (Fe_3O_4 NPs)

To synthesize iron oxide NPs, a 100 ml solution of $FeCl_2.4H_2O$ (0.4 M) was combined with an equal volume (100 ml) of plant extract solution; the resulting mixture was then heated to 100°C for 60 minutes and looked for color changes. The reaction mixture was then cooled and repeatedly washed by pelleting and washing in a 4,000 rpm centrifuge. Eventually, the pure-washed Fe_2O_3 NPs were obtained (Figure 2) and subjected to various characterizations. The synthesis of Fe-NPs was confirmed by the mixture's characteristic dark brown color change, signifying the reaction that occurred and the formation of the nanocomposite [49].

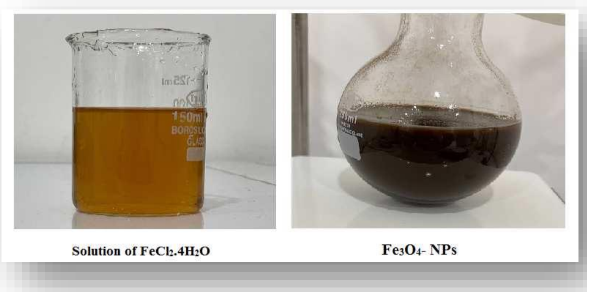

Figure 2. Synthesis of iron oxide nanoparticles (Fe_3O_4 NPs)

2.4. Identification of Fe3O4 NPs ' Antibacterial Activity

The prepared nanoparticles' biological activity was found using the well diffusion method. Follow the manufacturer's instructions. Iron oxide NPs (Fe_3O_4 NPs) were used at concentration (100) µg L^{-1}, at a temperature of 37 degrees Celsius and incubated for 24 hours. The resulting diameter of inhibition was then recorded [50].

3. Results and Discussion

3.1. Scanning Electron Microscopy

The morphology, sticking, and dispersion details of the synthesized Fe_2O_3 NPs are revealed by TEM observation at different magnifications. The produced nanoparticles ranged in size from 21 to 82 nm. The altered reactant concentration of iron chloride and plant extract resulted in irregularly shaped particles on the NPs ' surface. It was discovered that the majority of the artificially created Fe_2O_3 NPs were rod- and circular-shaped. Strong dispersion that improved the properties of the NPs was revealed by the TEM analysis (Figure 3).

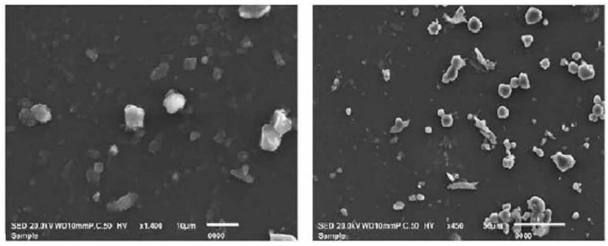

Figure 3. TEM image of iron oxide nanoparticles (Fe_3O_4 NPs)

3.2. FT-IR Analysis of (Fe_3O_4 NPs)

Figure 4 displays the obtained Fe_3O_4 NPs' FT-IR spectrum. Because of the iron oxide skeleton, the iron oxide FT-IR spectrum shows prominent bands in the low-frequency range (1000–500 cm^{-1}). In Figure 4, the Fe–O characteristic band at 626.87 cm-1 indicated the presence of Fe_3O_4. The characteristic stretching vibration of OH peaked at 3400.5 cm-1. Fe $(OH)_2$, Fe (OH)3, and FeOOH can be inferred as a result of hydrolyzation on the Fe_3O_4 surface. In addition, the peak at 1625.99 cm-1 indicates the presence of Fe–O.

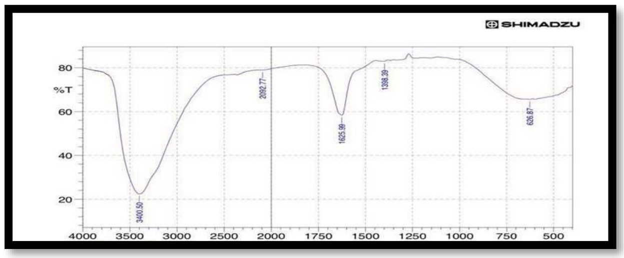

Figure 4. FT-IR analysis of iron oxide nanoparticles (Fe_3O_4 NPs)

3.3. UV-Visible Spectrophotometer of (Fe_3O_4 NPs)

UV-visible absorption spectroscopy (Figure 5), one of the key methods to confirm the formation of metal NPs given the presence of surface plasmon resonance for the metal, was used to track the formation of nanometal. In order to investigate the absorption spectra of green synthesized Fe-NPs, UV/Vis spectral analysis was performed at a wavelength range of 200-600 nm. The excitation of surface plasmon vibrations in FeNPs resulted in absorption peaks being observed at 223-303 nm ranges.

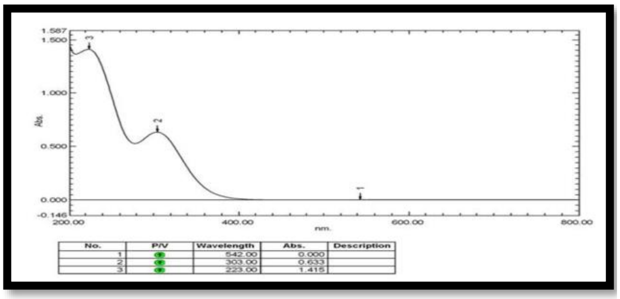

Figure 5. UV-visible spectrophotometer of iron oxide nanoparticles (Fe_3O_4 NPs)

3.4. Antimicrobial Activity of Iron Oxide Nanoparticles (Fe_3O_4 NPs) against Microbial Isolates

The antimicrobial effect was investigated against Gram-negative bacteria (Escherichia coli). The antibacterial activity of E. coli was determined, and the highest zone of inhibition was observed at the concentration of 100 µg/mL (Figure 6).

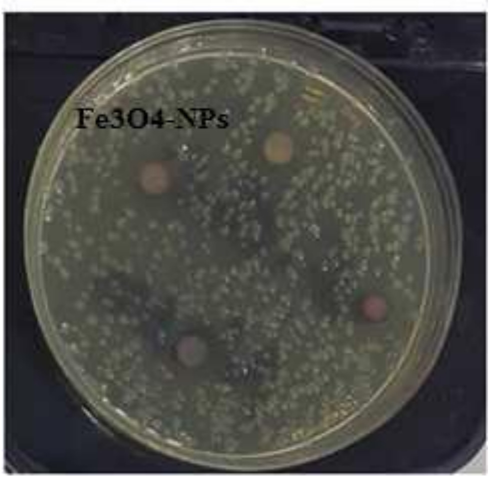

Figure 6. Antimicrobial activity of iron oxide nanoparticles (Fe_3O_4 NPs)

4. Conclusion

In conclusion, we have created Fe_3O_4 NPs through a simple, green chemical process that is also commercially feasible. The produced nanomaterials were thoroughly examined with a variety of specialized instruments, demonstrating the production of crystalline, spherically-shaped, and extremely stable Fe_3O_4 NPs in conjunction with functional groups of bioactive compounds. Since the synthesized Fe_3O_4 NPs are effective against E. coli and other bacterial human pathogens, they can be used as antibiotics.

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