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Green synthesis of nickel ferrite nanoparticles using *Terminalia catappa*: Structural, magnetic and anticancer studies against MCF-7 cell lines

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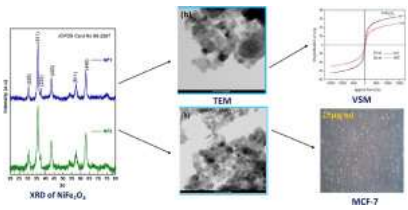
Highlights

- Nickel ferrite nanoparticles were synthesized using *Terminalia Catappa* leaves through a green approach method.
- Nickel ferrite nanoparticles were characterized by structural and morphological studies.
- Magnetic studies of synthesized nanoparticles showed variation in the saturation magnetization with variable green extract.
- Cytotoxic activity of nickel ferrite nanoparticles on breast cancer (MCF-7) cell lines was examined using MTT assay.

Abstract

Globally, cancer is among the leading causes of mortality, in 2020 it leads to nearly 10 million deaths. Breast cancer stands at first with around 2.26 million cases as per the reports of the World Health Organization. A cost-effective facile green synthesis method was used to prepare nickel ferrite ($NiFe_2O_4$) nanoparticles using different volumes (X=10 and 20 ml) namely samples NF1 and NF2 respectively from the leaf extract of *Terminalia catappa*. X-Ray Diffraction (XRD) analysis revealed that NF1 and NF2 samples showed inverse spinel structure with average crystallite sizes of 11.78 and 8.01 nm. Fourier Transform Infrared Spectroscopy (FTIR) spectral analysis of NF1 confirmed the formation of spinel ferrite. The agglomerated and spherical structure of nanoparticles is confirmed by Field Emission Scanning Electron Microscopy (FESEM) analysis. Energy Dispersive X-ray Analysis (EDAX) displays the presence of elemental composition of synthesized samples. The nanoparticles mediated by *Terminalia catappa* have spherical shapes with particle sizes of 21.41 nm and 19.30 nm. The Selected Area Electron Diffraction (SAED) pattern of $NiFe_2O_4$ nanoparticles confirmed the existence of polycrystalline nature. Magnetic studies showed a decrease in saturation magnetization considerably from 0.31 to 0.29 emu/g with an increase in the volume of leaf extract. Using different volumes of leaf extract is the critical parameter for the control of the size and shape of as-synthesized nanoparticles. The anticancer activity of breast cancer (MCF-7) cell lines revealed that cytotoxicity effects of sample NF1 with the lowest cell viability 24.92% at 500 µg/ml showed potent effectivity compared to NF2.

Graphical Abstract



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Keywords

$NiFe_2O_4$; XRD; FESEM; HRTEM; VSM and Breast cancer

1. Introduction

In recent years, the use of magnetic materials has vastly increased in biomedical applications (Andhareetal., 2020; Salavati-Niasari,2019). Magnetic nanoparticles play a crucial role in today's modern technology by finding applications in microwave devices, high sensitivity sensors, ferrofluids, catalysis, magnetic recording devices, etc. With the expanded applications of magnetic nanomaterials in these areas, there is an increased demand for the synthesis of magnetic nanoparticles with controllable structures and compositions (Liuetal., 2014; Motaharietal., 2015; Singhetal., 2021).

Furthermore, nanoscale magnetic nanoparticles have advantages that provide many exciting opportunities in biomedical applications such as radiation cancer therapy, genetic screening, magnetic resonance imaging and hyperthermia agents (Gaoetal., 2009, Monsefand Salavati-Niasari,2022; Niasariand Davar,2006; Salavati-Niasari,2020).

Spinel ferrites are fundamental complex oxide of iron, typically emerged as the most favorable magnetic material in many applications in water purification, catalysis, bioscience, optics, Ferrofluids, cellular signaling, hyperthermia, biosensors, and biomedicines such as drug delivery (Almessiereetal., 2022; Singhetal., 2022). Nickel ferrite spinel belongs to a special class of magnetic materials developed for a wide range of engineering applications like microwave absorbers, magnetic devices, switching devices, active components of ferrofluids, microwave absorbers, anti-cancer drugs, drug delivery, magnetic cell separation, colour imaging, magnetic refrigeration, permanent magnets, magnetic resonance imaging (MRI) and catalysis (Saranyaetal., 2018; Amiriaetal., 2017; Zinatloo-Ajabshiretal., 2020). Magnetic properties of nickel ferrite depend on the type of cations and their distribution between tetrahedral and octahedral sites (Bharatietal., 2020; Zinatloo-Ajabshiretal., 2018; Davaretal., 2010).

Depending on the particle size and shape, it exhibits paramagnetic, ferromagnetic and superparamagnetic behaviours (Nayaketal., 2022; Singhetal., 2022; Ponnammaetal., 2020). Several methods were used to synthesize $NiFe_2O_4$ nanoparticles including sol-gel, sonochemical, co-precipitation, reverse micro emulsion technique, etc. (Nadumaneetal., 2019; Shafietal., 1997; Joshietal., 2014; Gaoetal., 2011). Nickel ferrite nanoparticles are used in biomedical applications including cell labelling, cancer hyperthermia, magnetic resonance imaging and drug delivery. Despite their various applications, $NiFe_2O_4$ nanoparticles were little known about their toxicity. H. Q. Alijani etal. synthesized bimetallic nickel-ferrite nanorod particles using rosemary leaf extract and showed cytotoxicity effect on MCF-7 cells (Alijanietal., 2019). Ahamed etal. has studied comparative cytotoxic response of nickel ferrite nanoparticles in human liver HepG2 and breast MCF-7 cancer cells and observed that MCF-7 cells were slightly more susceptible to nickel ferrite nanoparticles exposure than HepG2 cells (Ahamedetal., 2015). Abasalta etal. has prepared carboxymethyl chitosan/poly (ε-caprolactone) doxorubicin/nickel ferrite core-shell fibers for controlled release of doxorubicin against breast cancer. The synthesized CMC/PCL/nickel ferrite 10% nanofibers and EMF showed maximum cytotoxicity against MCF-7 breast cancer cells (Abasaltaetal., 2021).

Terminalia catappa Linn also known as tropical almond present in sub-tropical and tropical zones. The leaves of *Terminalia catappa* contain several bioactive components such as antioxidants, flavonoids like tannins, phenols, kaempferol and polyphenols (Devadigaetal., 2017). Among the various bioactive components present in tannins, punicalin and punicalagin (Fig. 1) are the active components of *Terminalia catappa* and possess strong antioxidative activity (Linetal., 1999). Furthermore, the preparation of nanoparticles using natural plant extracts is simple, inexpensive and environmentally safe for human therapeutic use (Kombaiahetal., 2018) Table 1 gives the comparison of green synthesized $NiFe_2O_4$nanoparticles with reported works .