Special Issue on Chemistry

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Issue Editor
Dr. A. Manikandan

Research Journal of Agricultural Sciences
An International Journal

P- ISSN: 0976-1675
E- ISSN: 2249-4538

Volume: 13
Issue: Special

Res. Jr. of Agril. Sci. (2022) 13(S): 083–087

CARAS

Res. Jr. of Agril. Sci. (2022) 13(Special): 083–087

www.rjas.org

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Full Length Research Article

Microwave Synthesis and Magnetic Properties of Spinel $CoFe_2O_4$ Nanoparticles using Prickly Pear Cactus (*Opuntia fuliginosa*) Plant Extract

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Received: 07 Dec 2021 | Revised accepted: 15 Feb 2022 | Published online: 25 Feb 2022
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ABSTRACT

Spinel $CoFe_2O_4$ nanoparticles were synthesized by microwave heating method using prickly pear cactus (*Opuntia fuliginosa*) plant extract as a bio reducing agent. The obtained samples are analyzed by chemical and physical properties. Average crystallite size (nm) is discovered to be fluctuating between 19 - 24 nm. The surface morphology was dissected by utilizing SEM and TEM analysis. The metal oxide (M-O) band extending vibrations was confirmed by infrared spectral analysis. Spinel $CoFe_2O_4$ NPs can be raised as a noticeable antibacterial activity against human pathogens, due to their smaller size and higher surface area of the samples.

Key words**:** *Opuntia fuliginosa*, Microwave heating, $CoFe_2O_4$ NPs, FTIR, XRD, TEM, Antibacterial activity

In recently years, spinel ferrites with general recipe AB_2O_4 (A: Zn, Co, Cu, etc.) have fascinated a lot of attention as a result of the physical, chemical and biomedical properties [1-5]. The AB_2O_4 is the overall recipe for this spinel structure. Various techniques, such as sol-gel [6], co-precipitation [7], hydrothermal [8] method, etc. have been reported. It is utilized to noticeable light photocatalysis [9]. Mixed oxides with spinel type materials are furthermore among the gigantic number of photocatalyst pieces researched. Semiconductor materials are along with the bigger part potential photocatalysts for hydrogen age since they contain sensitive constancy, fixed temperament and thermodynamically best band structures [10]. The microwave heating method is the standard procedure for the synthesis of $CoFe_2O_4$ [11-12]. The $CoFe_2O_4$ is a confined band-opening semiconductor fabric, which have gigantic view for applications in clear light photocatalysis [13–16]. The Fe-O-Fe bond point is a scale to register the degree of distortion which impacts the hidden, optical, appealing, dielectric and various properties of the compound [17]. MFe_2O_4 pottery creation have been the goal of considered experts on account of their valuable properties in different applications going from solid oxide power gadgets [18], sensors [19], and normal driving forces [20].

Researchers are looking for new methods to treatment [21]. Recent findings suggest that a number of nanomaterials induce neuroprotective effects and preserve neuronal life. These nanomaterials are deployed due to their nanometer size, antioxidant properties [22], minimal toxicity, magnetic properties [23-25], etc. In recent decades, ferrite magnetic nanoparticles (NPs) with the chemical formula of AFe_2O_4 (A: Zn, Co, Cu, etc.) [26-30] have attracted the attention of researchers in various biomedical fields including drug delivery etc. are of particular importance in neuroprotection and also can be employed as magnetic resonance imaging (MRI) contrast agents [31-33]. Cobalt ferrite NPs are ceramic nanoscale materials [34-38], which can be deployed different biomedical and biological applications. In this study, Cobalt ferrite NPs were eco-friendly synthesized using prickly pear cactus (*Opuntia fuliginosa*) plant extract as a bio reducing agent. The physicochemical properties of $CoFe_2O_4$ NPs were determined by XRD, SEM, TEM, and VSM analyses. Spinel $CoFe_2O_4$ NPs can be raised as a noticeable antibacterial activity against human pathogens, due to their smaller size and higher surface area of the samples.

MATERIALS AND METHODS

Everyone chemicals of elevated purity marks were used without further sanitization. Iron (III) nitrate ($Fe(NO_3)_3$. $9H_2O$,99.9%), Cobalt (II) nitrate ($Co(NO_3)_2.6H_2O$,99.98%) were obtained from Sigmae Aldrich. Prickly pear cactus (*Opuntia fuliginosa*) plant extract was used for synthesis of $CoFe_2O_4$.

Iron (III) nitrate, cobalt (II) nitrate (Sigma-Aldrich, 99%), and Prickly pear cactus (*Opuntia fuliginosa*) plant extract were utilized for the green synthesis of $CoFe_2O_4$ NPs. Deionized water was utilized in all stages of the synthesis. Prickly pear cactus (*Opuntia fuliginosa*) plant extract were

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washed with deionized water. Plant moisture was removed at 50°C. To each gram of watercress powder, 10 ml of deionized water was added and shaken at 50°C, overnight. Finally, the extract was separated with Whatman paper and centrifuged. Iron (III) nitrate, cobalt (II) nitrate solution was added to 50 ml of aqueous extract. The mixture was kept in a microwave oven. The final product were washed well with DI water and ethanol twice finally dried at 70°C and used for further characterizations.

RESULTS AND DISCUSSION

XRD analysis

In microwave heating helped union procedure, metal salts were blended in with urea earlier than microwave treatment. The ensuing combination was then exposed to microwave light to accomplish spinel $CoFe_2O_4$ as of nitrate salt of as well as iron and cobalt. The phase and immaculateness were portrayed by combined materials as displayed in Fig. 1. The pinnacles are listed to average nanoparticle design of $CoFe_2O_4$ alluding to the nanoparticle nature of cubic structure. The crystallite size (D) of the example is assessed utilizing Scherrer's eqn. 1 [21]:

$$D = \frac{k\lambda}{\beta\cos\theta} ---------(1)$$

where L is the crystallite size, λ, the X-ray wavelength, θ, the Bragg diffraction angle and β, the full width at half maximum (FWHM). The average crystallite size 'L' calculated from the diffraction peaks was found to be around 23 nm.

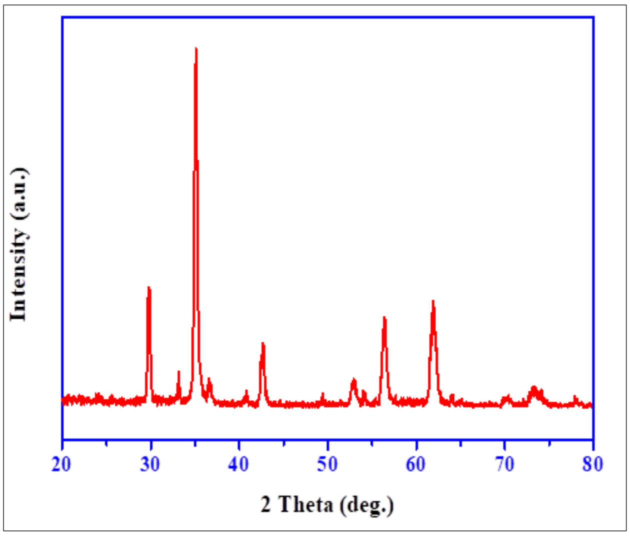

Fig 1 XRD patterns of $CoFe_2O_4$ nanoparticles

Morphological studies

SEM and TEM investigation (Fig. 2a and 2b respectively) takes spinel state of $CoFe_2O_4$ as additionally affirmed by XRD result. SEM and TEM portrays miniature construction with gem specifics of microwave incorporated $CoFe_2O_4$. The cross-section planes with unidirectional course of action express by presence of crystalline nature of $CoFe_2O_4$. Basic SAED examples of these examples (Fig. 2c) show ring designs, demonstrating a crystalline dependable with the XRD results.

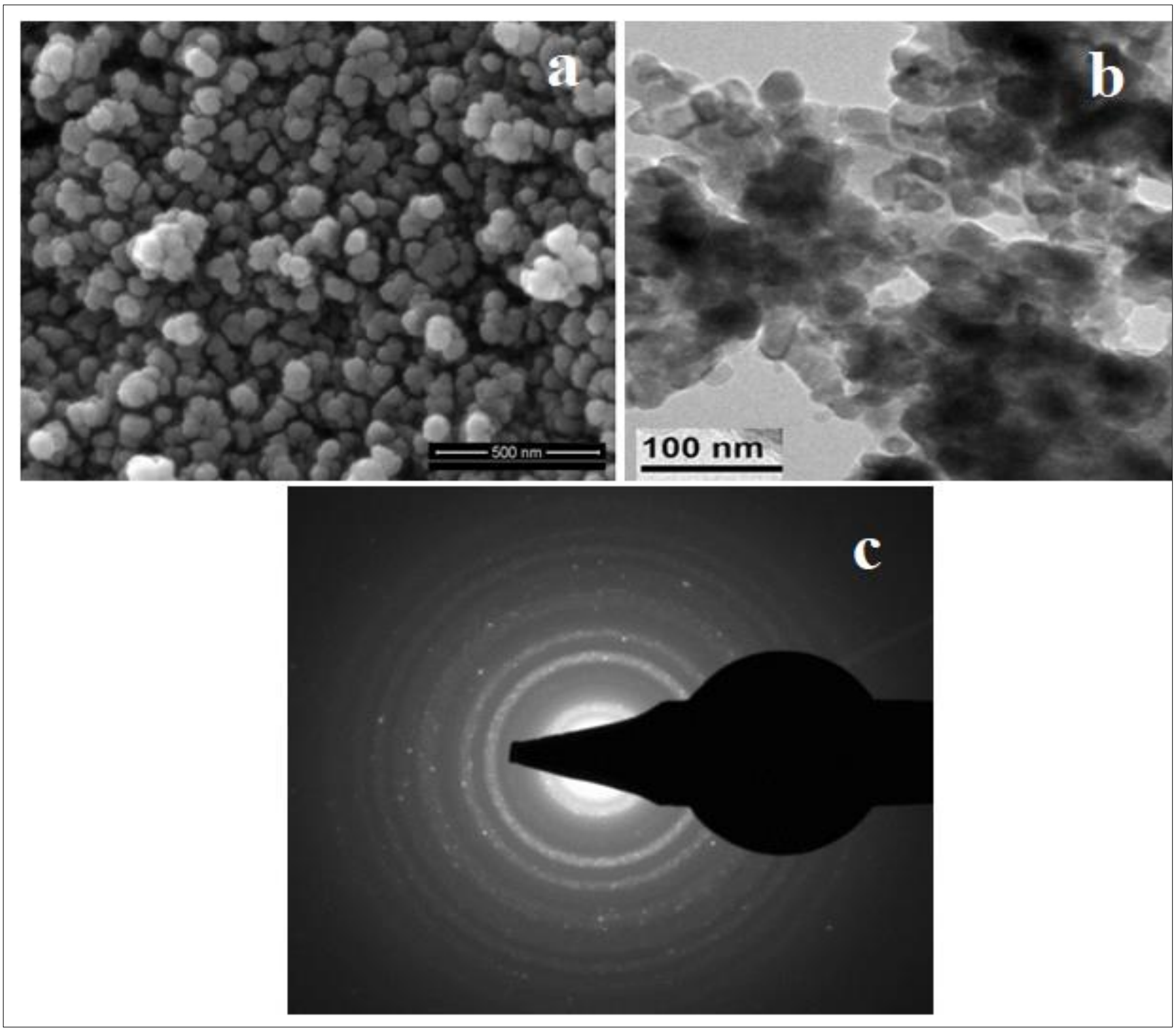

Fig 2 SEM (a), TEM (b) and SAED (c) pattern of $CoFe_2O_4$ nanoparticles

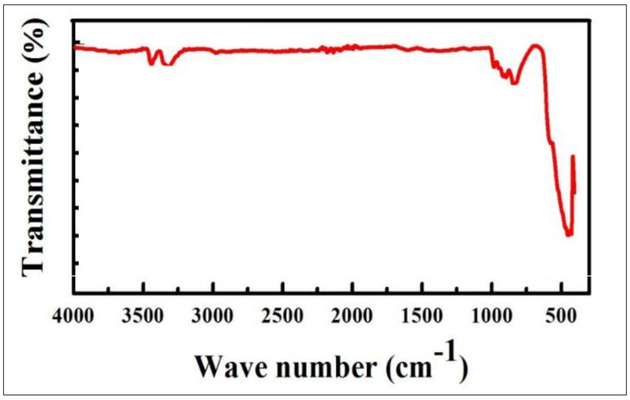

Fig 3 FT-IR spectra of $CoFe_2O_4$ nanoparticles

FT-IR analysis

The Fourier change infrared spectra (FTIR) of $CoFe_2O_4$ nanoparticles are shown in Fig. 3. The expansive retention band around 420 – 800 cm^{-1} Shows in all spectra. A little shift frequency of 546 cm^{-1} is distinguished for metal – oxide (M – O). The wave number of 3420 cm^{-1} is more ingestion band is noticed water molecules [22]. The bowing methods of O-H band are seen in roughly 1372 cm^{-1} and 1620 cm^{-1}. The metal – oxide groups presence of the little ingestion top at 420 – 800 cm^{-1} which the vibrations of spinel ferrites bonds are allotted [23].

Photocatalytic evaluation

The photocatalytic dye degradation using $CoFe_2O_4$ nanoparticles for Congo Red (CR) and obtained results are shown in Fig 4. The interest of Congo Red dye was kept up with after lighting for 2 hrs in the shy of the photocatalyst, which affirms that there was no photolysis of Congo Red. It is remarkable that Congo Red nearly corrupted ~94% under noticeable light brightening inside 120 min over $CoFe_2O_4$ nanoparticles.

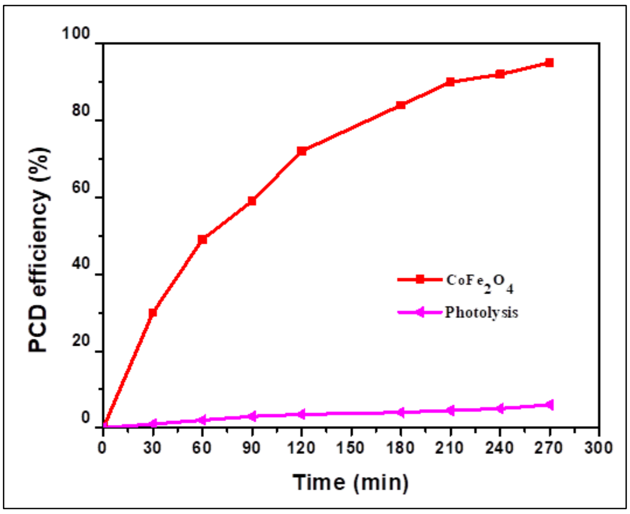

Fig 4 Photocatalytic degradation of Congo Red using $CoFe_2O_4$ nanoparticles

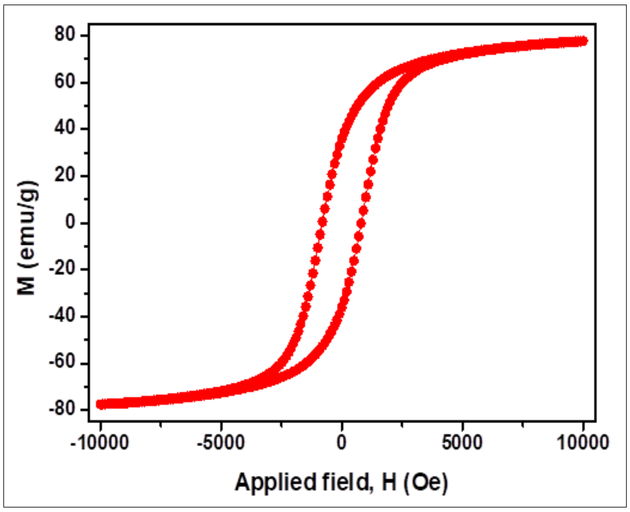

Fig 5 VSM analysis of $CoFe_2O_4$ nanoparticles

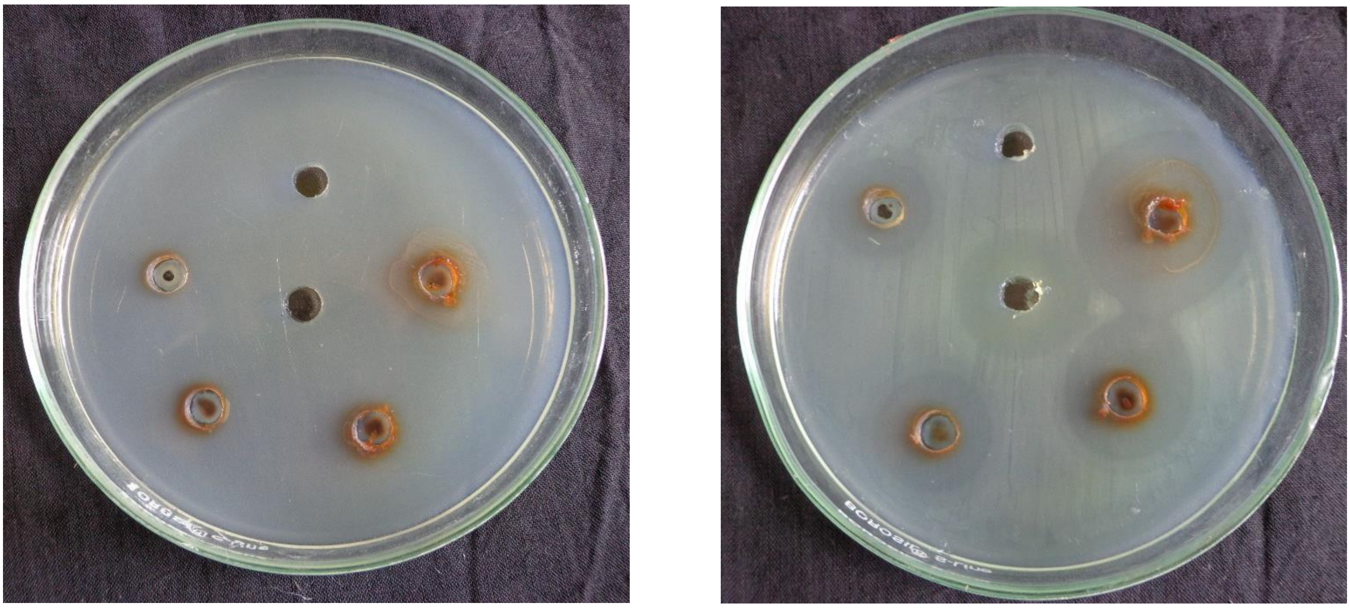

Fig 6 Antibacterial activity of $CoFe_2O_4$ nanoparticles

VSM analysis

Magnetic hysteresis (M-H) curves recorded at room temperature (RT) shows in Fig. 5. From the M-H loop it was observed the magnetic property of $CoFe_2O_4$ nanoparticles. The M^s value is 77emu/g. However, the permeability spectrum of general characteristics Ms remains constant in a convinced frequency range. The advent of Ms is due to the casing of the motion of the domains with the applied field. Remanent magnetization (Mr) and coercivity (Hc) values are very low, which shows the soft magnetic nature of the samples.

Aantibacterial activity

The antibacterial activity was determined by well diffusion methods (Fig 6). About 25 mL of molten Mueller Hinton Agar was poured into a sterile Petri plate (Himedia, Mumbai, India). The plates were allowed to solidify, after which 18 h grown (OD adjusted 0.6)100 µl of above said pathogenic bacteria cultures were transferred onto plate and made culture lawn by using sterile L-rod spreader. After five min setting of the bacteria, the wells were made using sterile 5 mm cork borer and test samples were dissolved in sterile water at various concentrations (i.e., 25, 50, 75 and 100 µl/well). The sterile water served as control. The plates were incubated at 37°C in a 40 W fluorescent light source (~ 400 nm) for 24 h. The antibacterial activity was determined bymeasuring the diameter of the zone of inhibition around the well using antibiotic zone scale (Himedia, Mumbai, India). The given samples were capable to kill all the tested pathogensranging from 6 mm to 29 mm of zone of inhibition (Refer Figures). The test materialshighlyactive against all test pathogens.

CONCLUSION

In this work, $CoFe_2O_4$ nanoparticles can be effectively prepared by microwave method using prickly pear cactus (*Opuntia fuliginosa*) plant extract as a bio reducing agent. Powder XRD results signify the pure spinel phase $CoFe_2O_4$ nanoparticles. XRD, SEM, TEM, FTIR, VSM and photo degradation studies were carried out. $CoFe_2O_4$ nanoparticles exhibited improved absorption ability especially in the visible light region. The photocatalytic exercises of the pre-arranged photocatalysts were assessed by photocatalytic debasement of CR under apparent light illumination. It was discovered that $CoFe_2O_4$ nanoparticles photocatalysts showed a lot higher photocatalytic action. The ferromagnetic behaviours saw from magnetic - hysteresis loop.

Acknowledgment

The authors are thankful to Tamil Nadu State Council for Science and Technology (TNSCST), DOTE Campus, Chennai for the financial support (S&T Project: TNSCST/ STP-PRG/AR/2018-2019/9307).

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