Comparative Study of Chitosan Encapsulated Nickel Nanoparticles and its Biomedical Application

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Abstract

Nanoparticles of nickel ferrite encased in chitosan were synthesised using the co-precipitation technique. Nickel ferrite is a soft substance with various technological uses, including in biomedical research and catalysis, and is one of the most desirable classes of materials overall. The co-precipitation approach is the primary emphasis of this work, followed by a comparative analysis of NiFe2O4 nanoparticles synthesised with citric and oxalic acids. The samples were characterised using the following techniques: energy dispersive X-ray spectroscopy, scanning electron microscopy (SEM), and X-ray powder diffraction (XRD). Both bacterial strains were inhibited by the NiO nanoparticles, with the greatest selectivity shown against gram-positive bacteria.

Index Terms-Chitosan, Citric acid, Nickel ferrite nanoparticles, and Oxalic acid.

1. INTRODUCTION

Chitosan, which is either entirely or partly deacetylated chitin, is an intriguing polymer that has found widespread use in healthcare. According to Hebzi Emalda Rani et al. (2020), chitosan is a natural polymer that is neither biodegradable nor biocompatible. A significant magnetic material, nickel ferrite has several uses including catalysis, magnetic refrigeration, and the production of ferro fluids [Sonvico, C. Dubernet et al.,2005,

According to Hajdú, Tombácz et al. (2008), L. Chauhan, A. K. Shukla (2015), and other researchers, this soft ferrite is very significant because to its excellent chemical stability, low coercivity, high mechanical hardness, and excellent electromagnetic performance. Due to their magnetic properties, ferrite nanoparticles have been the focus of intensive and substantial study [S.-Y. Yu, H.-J. Zhang, J.-B et al., 2007]. Nickel ferrite is a soft ferrite material that is abundant in nature, has excellent electrochemical stability, is catalytic, has low conductivity (and hence lower eddy current losses), and is known for its typical ferromagnetic properties [Ranjbar, Naderi et al., 2014]. It has been shown that ferrite materials may effectively block and remove ratio frequency interference from audio systems in recent times [Gunakar JL et al., 2008]. According to Saffari, Shams, et al. (2014), nickel ferrite has magnetic characteristics that are comparable to those of magnetite and maghemite. Synthesis of nickel nanoparticles using the co-precipitation technique and comparison of oxalic and citric acid are the primary foci of this work.

11. MATERIALS AND METHOD

The crab shells were retrieved from the Rameswaram beach, which is a site of crustacean trash. After removing any loose tissue, washing, and drying the shells, they were put through a 0.3-0.55 filter to remove impurities. Then, they were demineralized, deproteinized, and deacetylated until they were left with chitosan powder. Chitosan was kept at room temperature pending more research.

A. SYNTHESIS OF NICKEL FERRITE NANOPARTICLES

The first step was to make separate solutions of 0.2 M NiCl2 and 0.4 M FeCl3 6H2o. After combining the solutions, sodium hydroxide solution (3M) was added drop by drop until the pH was adjusted to around 13.There are three sections to this section. As a surfactant, oleic acid was added to the solution in 1/3 of the total volume, followed by citric acid, and finally, oxalic acid. After that, the temperature was raised to 800C for 40 minutes for each component. Multiple washes with ethanol and water followed centrifugation of this solution.

13. The precipitation was dried in an oven at 80^0C for 6
hours. Amorphous NiFe o nanoparticles were

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obtained at this stage. This sample was stored at room temperature for further studies.

B. CHITOSAN COATING PROCESS

Chitosan solution of 0.5wt % were prepared by dissolving required amount of chitosan powder in 40 ml of 2% acetic acid solution which were divided into three parts. Each part added with $NiFe_2O_4$ nanoparticles obtained from metals like citric and oxalic acid were blended with prepared 0.5wt chitosan solution with vigorous stirring. To this added 10 ml of 25% NH_4OH. After the reaction chitosan coated Nickel ferrite was washed with water resuspended in 20ml 0.5% acetic acid solution by magnetic stirring for 20 minutes. After that filtered and kept for drying in one hour. The collected various samples were used for further characterization.

111. RESULT AND DISCUSSION

A. X-RAY DIFFRACTION

The crystallinity, particle size, and purity of the produced catalysts were examined using X-ray diffraction (XRD) patterns. The XRD patterns of the NiFe2O4 samples that were calcinated are shown in figures 1a–c. The formation of nickel ferrite was shown in sample 1(a) by means of citric acid, oxalic acid (fig. b), and a combination of the two acids (fig. c). The X-ray diffraction pattern for nickel nanoparticles with citric acid exhibited a peak at 211,110,220, whereas the peak at 330,110,222 was for oxalic acid, and at 321,110,400 for both acids together. Figure c shows that the nickel crystallite sizes have grown, as shown by the most sharp diffraction peaks. The prominent and abrupt peak was seen when comparing oxalic acid and citric acid in this 1(fig c). The Debye-Scherrer equation may also be used to quantitatively quantify the particle sizes using the XRD data.

$$D=K\,\lambda/\beta\,\cos\theta$$

According to Debye-Scherrer equation, the size of the Nickel nanoparticles is about 16, 20 and 28 nm.

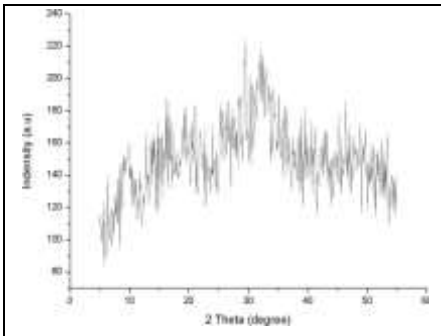

Fig.1(a) X-ray diffraction of $NiFe_2O_4$ using citric acid

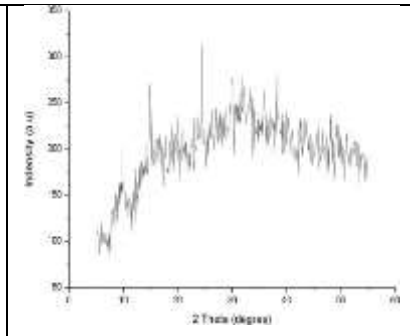

Fig.1(b) X-ray diffraction of $NiFe_2O_4$ using oxalic acid

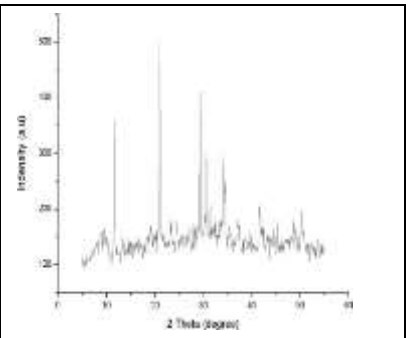

Fig.1(c) X-ray diffraction of $NiFe_2O_4$ using citric and oxalic acid

B. SCANNING ELECTRON MICROSCOPY(SEM) MICROGRAPH OF THE CHITOSAN NANOPARTICLES

One of the potent instruments for determining the nanoparticles' shape is the scanning electron microscope. Because of the agglomeration process, the particles take on a spherical form and resemble nanoclusters, as seen in Fig. (2a). According to Figure 2b,

fig. 2c depicted the plate-like structure that was found in the polymeric cell of chitosan. The inclusion of a cell component and the capping agent on the surface of the nanoparticles allowed for the comparison of these three structures, which is comparable to a previously published research utilising nickel oxide nanoparticles (Ref-9)

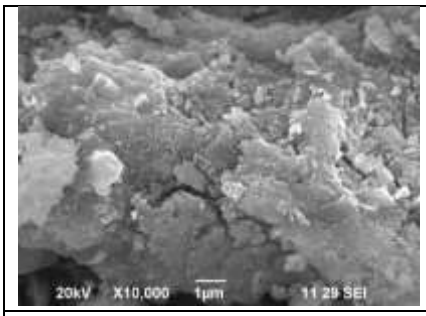

Fig.2(a) SEM image of $NiFe_2O_4$ using citric acid

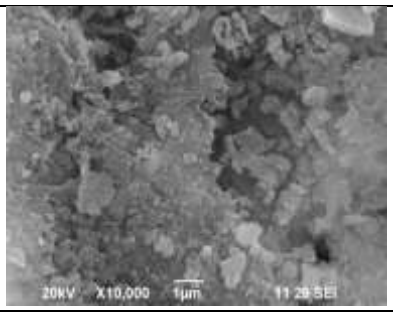

Fig.2(b) SEM image of $NiFe_2O_4$ using oxalic acid

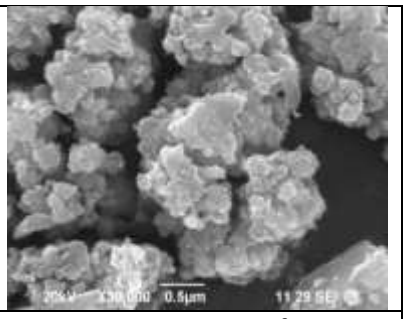

Fig.2© SEM image of $NiFe_2O_4$ using citric and oxalic acid

C. ENERGY DISPERSIVE X-RAY SPECTROSCOPY

An elemental composition study was conducted using energy dispersive X-Ray spectroscopy (EDX) to verify the existence of major elements in the synthesised materials. The method allows one to determine the chemical make-up of the materials underwent high-resolution analysis. The primary material components are validated using the EDX data. The weight percentage of nickel in chitosan powders was found to be 2.79% when citric acid was used (fig.3a), 4.42% when oxalic acid was used (fig.3b), and 1.24% when both acids were used (fig.3c).

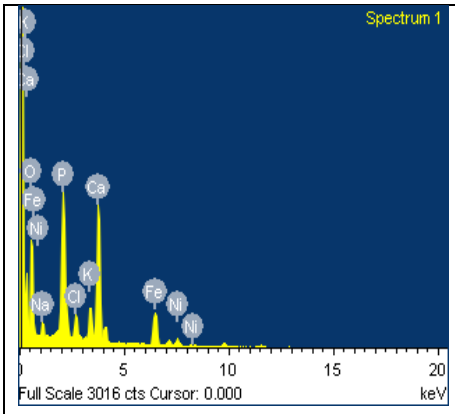

Fig.3(a) EDX spectrum of chitosan $NiFe_2o_4$ using citric acid

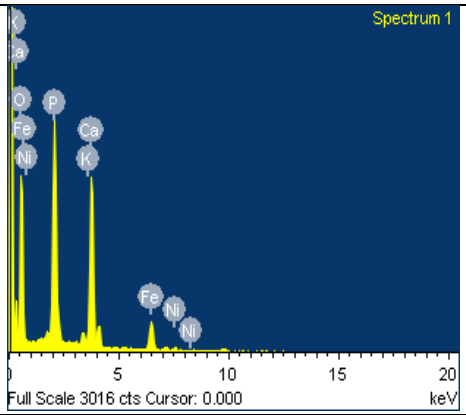

Fig.3(b) EDX spectrum of chitosan $NiFe_2o_4$ using oxalic acid

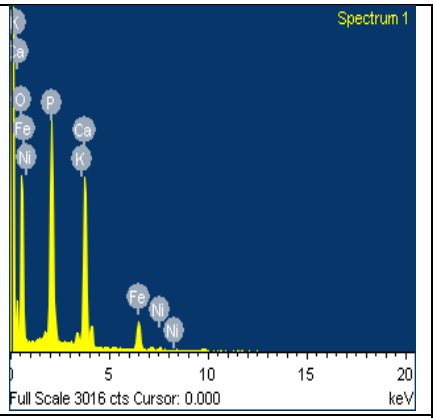

Fig.3© EDX spectrum of chitosan $NiFe_2o_4$ using citric and oxalic acid

1V. ANTIBACTERIAL ACTIVITY OF CHITOSAN NANOPARTICLES

It is claimed that the chitosan nanoparticles possess effective antimicrobial properties. Two distinct harmful microorganisms, including Staphylococcus aureus and Escherichia coli, were evaluated against the synthesised chitosan containing nanoparticles. The zone of inhibition for Staphylococcus aureus is 29 mm and Escherichia coli is 27 mm when the dose of standard Gentamycin is 80 mcg. Even at 40 mcg, Gentamycin had little effect against Escherichia coli but did have a 10-millimeter zone of inhibition against Staphylococcus aureus. the bactericidal action of nickel in combination with oxalic acid when used for

While Staphylococcus aureus has 29 and Escherichia coli has 27, as seen in figure 4a. Figure 4b shows that when citric acid is introduced instead of oxalic acid, the zone of inhibition for Staphylococcus aureus is 28 and for Escherichia coli it is 29. The combined antibacterial effects of citric and oxalic acid against Staphylococcus aureus are 27, and against Escherichia coli they are 29, when put together (fig.4c). The bactericidal activity of oxalic acid and citric acid was same. Oxalic citric acid has the most potent antibacterial action when compared to citric and oxalic acid.

Table:1 Antimicrobial activity against Escherichia Coli and Staphylococcus aureus for nickel nanoparticles using oxalic and citric acid

S.No	Sample	Organism	Zone of inhibition	
			Standard Gentamycin (80mcg)	T1 40µL from 10mg/ml
1.	Oxalic Acid	Escherichia coli	27	10mm
		staphylococcus aureus	29	-
2.	Citric Acid	Escherichia coli	29	10mm
		staphylococcus aureus	28	-
3.	Oxalic & Citric Acid	Escherichia coli	29	-
		staphylococcus aureus	27	-

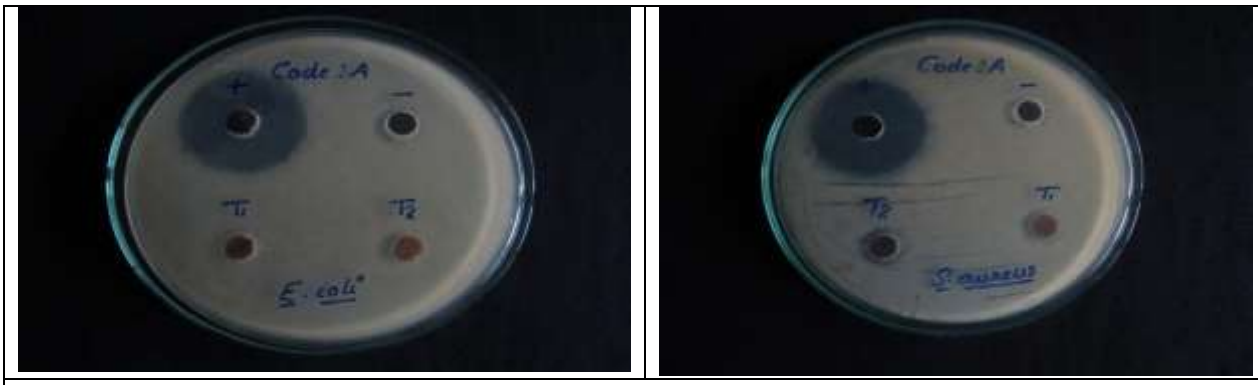

Fig.4a Antimicrobial activity against E.Coli and staphylococcus aureus for nickel nanoparticles using oxalic acid

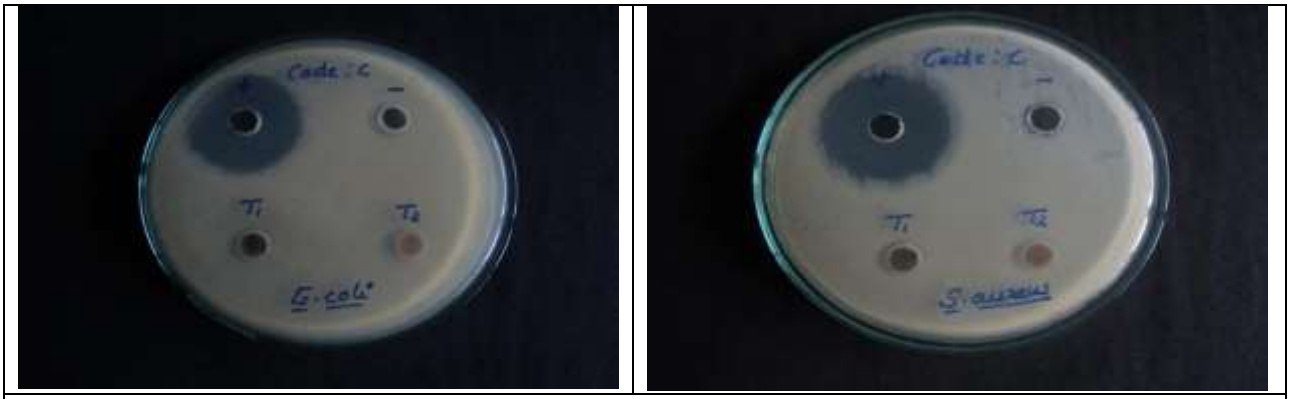

Fig.4b Antimicrobial activity against E.Coli and staphylococcus aureus for nickel nanoparticles using citric acid

Fig.4c Antimicrobial activity against E.Coli and Staphylococcus aureus for nickel nanoparticles using oxalic and citric acid

V. CONCLUSION

The current study demonstrated that chitosan-based co-precipitation methods were capable of efficiently producing nanoparticles of nickel oxide. Utilising XRD, SEM, and EDX, the synthetic NPS were thoroughly examined. Nanoparticles were tested for their antimicrobial efficacy against two distinct bacterial strains. The nanoparticles of nickel ferrite were verified by XRD. Oxalic and citric acid showed a clear and robust peak on the scanning electron microscope. With the use of energy dispersive X-ray spectroscopy, we were able to determine that the weight percentage of nickel while using citric acid was 2.79%, when using oxalic acid was 4.42%, and when using both acids together, it was 1.24%. Oxalic acid exhibits a high percentage when comparing the three weight groups. The inhibitory zones for Staphylococcus aureus and Escherichia coli are 28 and 29, respectively, when citric acid is introduced in place of oxalic acid. The combined antibacterial effects of citric and oxalic acid against Staphylococcus aureus are 27, and against Escherichia coli it is 29. The bactericidal activity of oxalic acid and citric acid was same. Oxalic citric acid has the most potent antibacterial action when compared to citric and oxalic acid.

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